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Dinosaurs
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FROM THE EDITOR

Why is there something, rather than nothing? Why does anything exist at all? Every culture has its own creation stories, but until recently, it's not something physicists had a satisfying answer for. Our best answer to that question, in scientific terms, is that 'something' is more stable than 'nothing'. Our best theories of the world of the infinitesimally small – the realm of quantum physics – have observed that the smallest particles can pop in and out of existence. That same theory predicts that at the smallest possible scale, bubbles of space-time – the fabric upon which everything exists – would blink in and out of nothingness. In the world of quantum theory, if something can happen, it does. So, it's possible our Universe was born out of a bubble that pinged into existence, went through a Big Bang, followed by inflation and then the expansion we see today. It's not got the same ring to it as seven days and seven nights, but it's the best we have. So far.

Physicist and computer scientist Stephen Wolfram thinks he might be closing in on a better answer, one that explains why these quantum rules exist in the first place. We asked Marcus Chown to investigate, so find out what he learned on p52.

Also, I'd like to turn your ears towards our brand new podcast, *Instant Genius*. With the help of world-leading scientists and experts, each episode delivers a 30-minute masterclass on some of the key ideas in science and technology today. To find us, head over to your favourite podcast app. The first few episodes are out now and include the Big Bang, Neanderthals, brain chemistry, dinosaurs, food science and the end of the Universe. See you there!

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Song Of The Reed: Summer
This new four-part series blends fiction with fact to offer listeners an insight into the work and science of conservation across the seasons. Recorded in the Strumpshaw Fen nature reserve in Norfolk, the story is voiced by Mark Rylance and Sophie Okonedo (pictured).
BBC Radio 4
21 June, 2pm

A Pandemic Poem: Where Did The World Go?
In a touching and poignant response to the past 18 months, *A Pandemic Poem* documents the resilience and the strength of communities, through the words of Poet Laureate Simon Armitage (pictured) and the people of Britain themselves.
Available on BBC iPlayer now

Bees In A Pod
In conjunction with BBC Radio 2's Big Bee Challenge, this new podcast showcases our favourite pollinators in the very best light. Featuring trusted experts and celebrity guests, episodes will help all listeners welcome more bees into outside spaces.
Available on BBC Sounds in July

COVER: ANDY POTTS THIS PAGE: GETTY IMAGES X3, DANIEL BRIGHT

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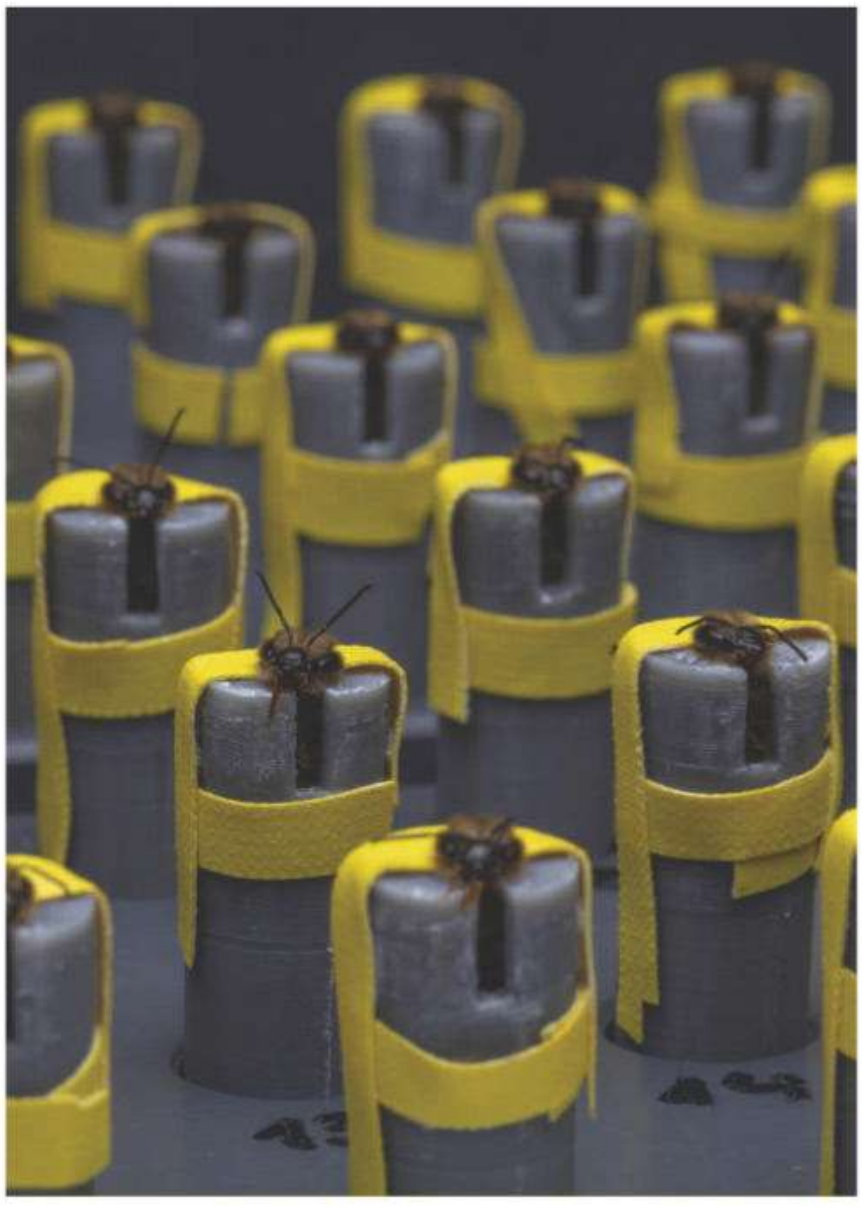

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"WHEN YOU SEE A NEWS STORY ABOUT AN 'EARTH-LIKE WORLD' YOU MIGHT AS WELL SAY 'VENUS-LIKE WORLD'. WE CAN'T TELL THE DIFFERENCE"

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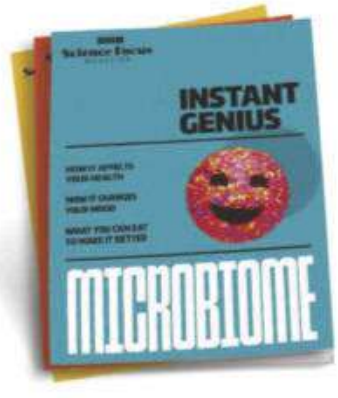

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A collection of the most important ideas in science and technology today. Discover the fundamentals of science, alongside some of the most exciting research in the world.

EYE OPENER

Family sticks together

JAPAN

This tiny creature could fit on the tip of your finger, though it would leave a sticky residue. On this blade of eelgrass, though, the adhesive organ on the back of this northern pygmy squid helps keep her from being swept away while she lays her eggs.

These animals only live for a few months, but once mature they reproduce through multiple matings.

"Females mate with males and store their sperm in small invaginations around the mouth, known as 'seminal receptacles'," explains Prof Louise Allcock, director of the Ryan Institute's Centre for Ocean Research & Exploration at NUI Galway. "As the female lays her eggs, she draws the sperm out of the seminal receptacles and fertilises her deposit."

This pygmy squid won't stay with her offspring, says Allcock. "In fact, she puts all her effort into egg laying and dies soon afterwards, as is quite normal in cephalopods."

TONY WU/NATUREPL.COM

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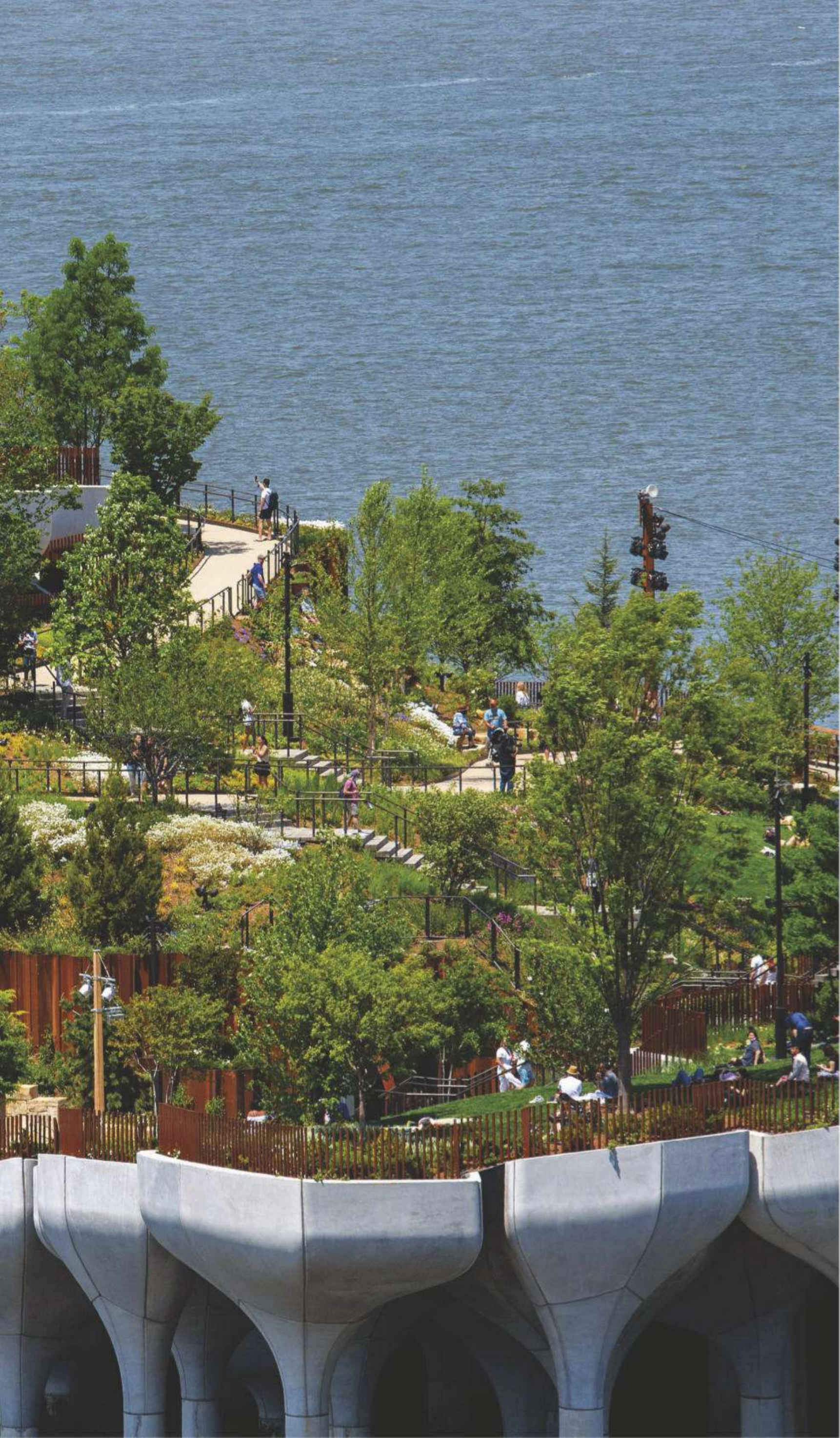

EYE OPENER

Tiny island

HUDSON RIVER, NEW YORK

After damage by Hurricane Sandy, an investment of $260m has turned Hudson River's pier 54 into a space of beauty and calm for both humans and wildlife.

Called 'Little Island', this new public park sits atop 132 concrete 'tulips', designed to hold different plants, shrubs and trees. Some 350 species have been planted across the area, while beneath the island, leftover wood piles from the original pier have been preserved in order to maintain pre-existing aquatic habitats.

Little Island hopes to offer a space of sanctuary, especially for those who don't have regular access to greenery.

"Research has shown that when people lived in greener areas, people were happier overall," says Wendy Masterton, a researcher in social and natural sciences at the University of Stirling. Millions of dollars sounds like a lot, but compared to the cost of individual treatments, a park in a city could benefit thousands and have a greater effect on a population, explains Masterton.

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LETTER OF THE MONTH

A rogue virus may have allowed the placenta to form

Early beginnings

Humans, along with all the primates, carnivores and rodents, have come a long way through natural selection and evolution.

The placenta would have played an important role in giving an edge over other animal forms, in the embryonic and neonatal life of the offspring's early life. Yet after being a medical consultant for four decades with a background knowledge of embryology, I remain completely ignorant of the origin of the placenta (perhaps an unexpected change of a microsomal protein?), and its evolution to the totally indispensable organ it has become today.

I would be grateful if you could enlighten us on this topic.

Dr Gamini Katugampola

Great question! Around 15 years ago, US scientists discovered two human 'syncytin' genes which are only active in the human placenta. Both genes look a lot like retrovirus genes. Other mammals also have genes in the placenta that resemble retrovirus genes. Scientists hypothesise that millions of years ago, mammals became infected with these viruses, which have been harnessed over time to assist with placental growth. Find out more here: bit.ly/virus_placenta

Alice Lipscombe-Southwell, *managing editor*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins an award-winning **Nextbase 622GW dashcam**. The dashcam features 4K video, super slow motion, enhanced night vision, along with what3words location technology that can pinpoint your location to within a three-metre area and share with emergency services. **nextbase.com**

Brontosaurus burgers for everyone

I was reading the 'In numbers' section in *Discoveries* which said "Eating meat three or more times a week increases risk of various illnesses". Our ancestors did eat meat and very little veggies/fruits/grains. So, are the risks due to processed meats/foods? Or is it due to lack of exercise, modern lifestyles, less physical jobs, etc, etc?

I found this science soundbite very unscientific and not useful.

Jan Voelker, Gahanna, Ohio

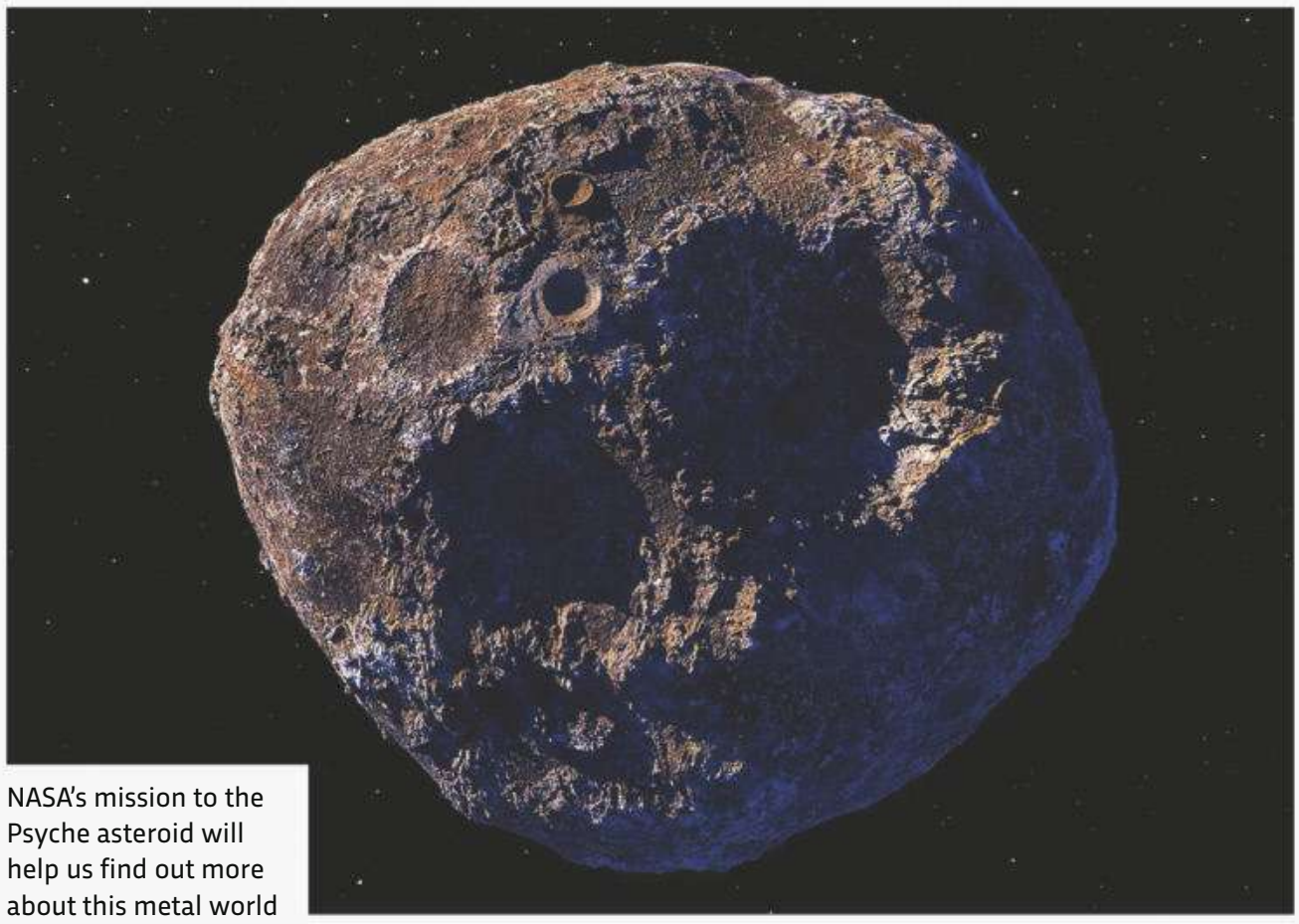
The illnesses in question were heart disease, pneumonia, diabetes, diverticular disease, colon polyps, gastro-oesophageal reflux disease, gastritis, duodenitis, and gallbladder disease, and the study comes from an analysis of the health records of nearly 500,000 British people who provided data for an average period of eight years – a pretty robust study.

The meat in question is all meats – red meat, processed meat, poultry, etc, with

Early humans did not exclusively chow down on a meaty menu

"GENERAL RELATIVITY AND QUANTUM THEORY ARE BASICALLY THE SAME THEORY! I NEVER EXPECTED TO DISCOVER SUCH A LOVELY RESULT"

STEPHEN WOLFRAM, P52



NASA's mission to the Psyche asteroid will help us find out more about this metal world

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different meat products raising the risk in different ways. Of course, other factors such as exercise, lifestyle, smoking, alcohol consumption and genetics affect mortality rates, but that wasn't the focus of the study.

The increased incidence of heart disease was likely due to the saturated fatty acids found in red and processed meats, while many of the other conditions were more common in individuals with higher BMIs.

Also, early humans didn't "eat meat and very little veggies/fruits/grains", they were omnivorous and likely ate a diet consisting mostly of plants that was supplemented with meat when they were able to get it.

Jason Goodyer, *commissioning editor*

It's a small world

I was reading Dr Stuart Clark's article about Psyche asteroid. Why does the science community seem to refer to the 'beginning' of the Solar System as a past event? What if the beginning is still unfolding right now? If so, what if we viewed Psyche and the rest of the asteroid belt not as leftovers, but as building materials that have yet to be used? Is it possible for Psyche to be a planet's core that has yet to merge with the rest of the planet it belongs to, rather than a core that was forcefully removed?

Teja Drayton

It's a nice idea but unfortunately the physics does not support the situation. Once large planets have formed, their forces of gravity dominate the situation. In this case, Jupiter's gravity corrals the asteroid belt, making their coalescence virtually impossible. Even if all the asteroids could come together, their combined mass would total just 3 per cent of the mass of the Moon. That's a very small world!

Dr Stuart Clark, *astronomer and astrophysicist*

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DISCOVERIES

AUSTRALIA'S LARGEST EVER DINOSAUR DISCOVERED

The 30m-long titan *Australotitan cooperensis* is believed to be one of the biggest dinosaurs on the planet

VLAD KONSTANTINOV/SCOTT HOCKNULL/EROMANGA NATURAL HISTORY MUSEUM

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Dr Scott Hocknall with a 3D reconstruction of *Australotitan*'s humerus bone, from its front leg

A newly discovered dinosaur has been named Australia's largest species. *Australotitan cooperensis* is between 5 and 6.5 metres tall at the hip and 25 to 30 metres long. It was estimated to weigh between 23,000 and 74,000kg when alive.

The dinosaur is a sauropod, a four-legged herbivore with a long tail and neck, like the well-known *Diplodocus*. More precisely, it belongs to the group of sauropods called titanosaurs, which contain the largest-known land animals ever to walk the Earth. The new dinosaur, which lived 92 to 96 million years ago in the Cretaceous period, is believed to be among the 10 to 15 largest dinosaurs worldwide.

Its name means 'southern titan from the Cooper', named after Cooper Creek in the Eromanga Basin, where it was discovered in 2007. Following its discovery, researchers had to study the fossil closely to tell whether it was a new species.

"*Australotitan* adds to the growing list of uniquely Australian dinosaur species discovered in outback Queensland, and just as importantly showcases a totally new area for dinosaur discovery in Australia," said Dr Scott Hocknull, senior curator at Queensland Museum. "To make sure *Australotitan* was a different species, we needed to compare its bones to the bones of other species from Queensland and globally. This was a very long and painstaking task."

This can be difficult to do, since dinosaur bones are not only enormous and heavy, but incredibly fragile. So, the researchers created 3D digital scans of each bone. "The 3D scans we created allowed me to carry around thousands of kilos of dinosaur bones in a 7kg laptop," said Hocknull. "Better yet, we can now share these scans and knowledge online with the world."

Compared to its closest relatives, *Wintonotitan*, *Diamantinasaurus* and *Savannasaurus*, researchers found that *Australotitan* was the largest of the family. "We compared the three species found to the north, near Winton, to our new Eromanga giant and it looks like Australia's largest dinosaurs were all part of one big happy family," said Hocknull.

Palaeontologists, geologists and volunteers from Queensland Museum and Eromanga Natural History Museum have worked together in the area for 17 years. In this time, they have found a large variety of fossils, many of which are still awaiting scientific study.

"Over the last 17 years, numerous dinosaur skeletons have been found, including one with an almost complete tail. The discovery of a rock shelf almost 100 metres long represents a sauropod pathway, where the dinosaurs walked along trampling mud and bones into the soft ground," Hocknull said.

"Discoveries like this are just the tip of the iceberg. Our ultimate goal is to find the evidence that tells the changing story of Queensland, hundreds of millions of years in the making. A grand story all scientists, museums and tourists can get behind."

"Discoveries like this are just the tip of the iceberg. Our ultimate goal is to find the evidence that tells the changing story of Queensland"

ROCHELLE LAWRENCE, DANIEL RAZANSKY/UNIVERSITY AND ETH ZURICH ILLUSTRATIONS: KYLE SMART

STRESSED-OUT STUDENTS

Scientists at the University of Washington have found that spending time with therapy dogs can help to improve stressed-out students' thinking and planning skills, with effects lasting for up to six weeks after the end of the six-week programme.

VEGETARIANS

Eating a plant-based or pescatarian diet may help to reduce the risk of developing moderate to severe COVID-19 infection by 73 per cent and 59 per cent respectively, an online survey of 2,884 frontline doctors and nurses, has found.

Good month

Bad month

SWEET MAKERS

Shoppers spend around £1.75 less on sweets and desserts when food shopping online compared to in-store, a study at the Harvard T.H. Chan School of Public Health, Boston, has found. This is due to in-store shoppers being more open to impulsive purchases, they say.

BEES

A study carried out at the University of Michigan has found that bees and other pollinators may find it difficult to cross roads. This results in a drop in the exchange of DNA between the pollinators and the plants they pollinate, which may lead to a loss in genetic diversity, and perhaps even to extinction.

BRAIN

Breakthrough scanning technique allows researchers to look deeper into the brains of living organisms

A team of researchers from the University of Zurich, Switzerland, have developed a non-invasive infrared scanning technique that allows them to produce images of the fine structure of the brains of living mice in unprecedented detail.

Dubbed 'diffuse optical localisation imaging', or DOLI, the technique is based upon a method of imaging known as fluorescence microscopy. In fluorescence microscopy, beams of high intensity light are directed at a fluorescent substance known as a fluorophore. The light is absorbed by the fluorophore and then emitted at a lower wavelength. This emitted light can then be filtered out from any surrounding radiation and used to construct an image.

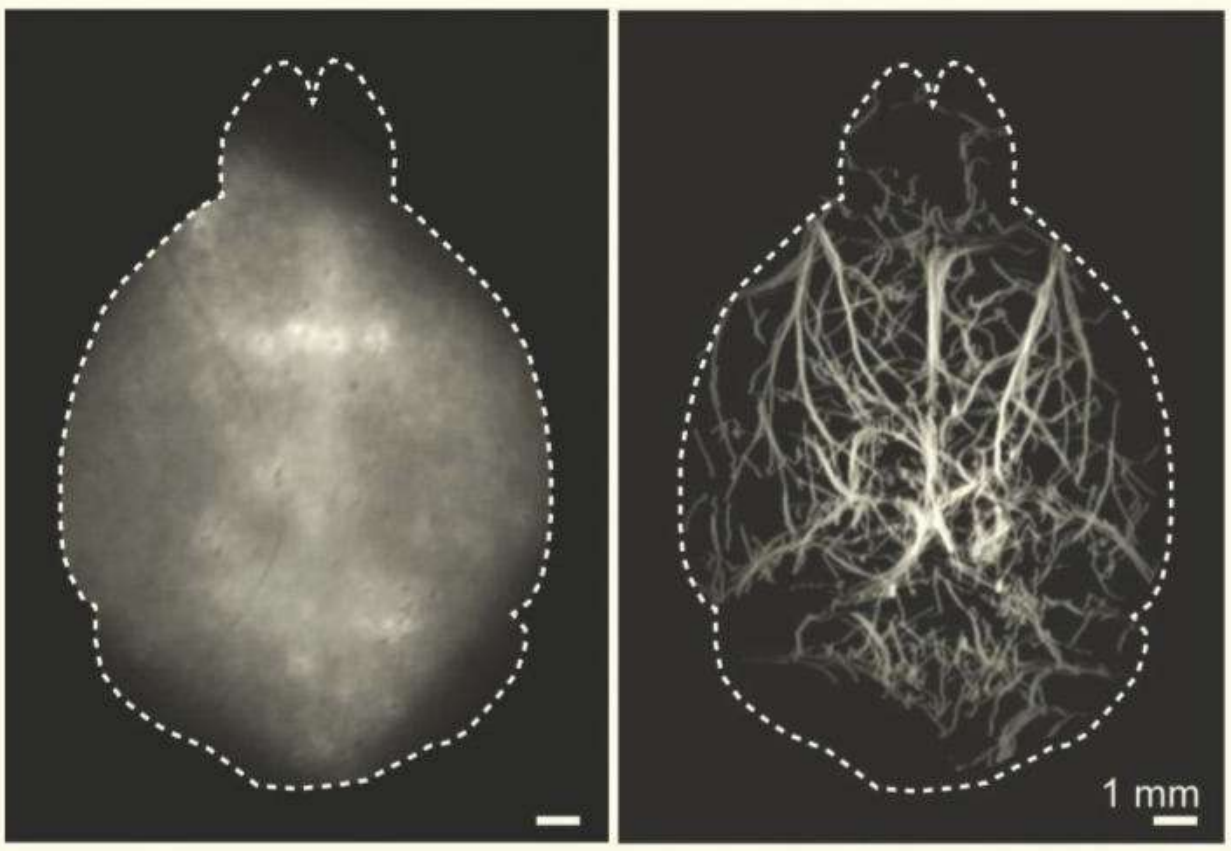
The technique has previously been used to image the brains of animals, but it was only able to image small areas at low resolutions due to the light being scattered by the animals' skin and skulls.

To overcome this, the team at Zurich used cutting-edge infrared cameras that can penetrate deeper into the animals' brain than previous devices and therefore experience far less scattering.

They tested their technique by injecting microscopic fluorophores into the bloodstreams of living mice. By tracking these particles as they flowed through the animals' brains using the new infrared cameras, they were able to construct a detailed image of the organs' fine microvascular structure.

"Our study represents the first time that 3D fluorescence microscopy has been performed fully noninvasively at capillary level resolution in an adult mouse brain, effectively covering a field of view of about one centimetre," said study team leader Prof Daniel Razansky.

"Enabling high-resolution optical observations in deep living tissues represents a long-standing goal in the biomedical imaging field. DOLI's superb resolution for deep-tissue optical observations can provide functional insights into the brain, making it a promising platform for studying neural activity, microcirculation, neurovascular coupling and neurodegeneration."



The new method can noninvasively capture images of the brain at the capillary level

ZOOLOGY

‘Scuba-diving’ lizards breathe underwater by attaching air bubbles to their snouts

Anole lizards found in the streams of Costa Rica can use the technique to stay submerged for up to 16 minutes

You’re having a bubble! Biologists at Binghamton in the US and the University of Toronto in Canada have found that several species of anole lizards have evolved to breathe exhaled air underwater using a pocket of air that clings to their snouts.

The team made the discovery after being shocked to observe the lizards spending long periods of time underwater, sometimes up to 16 minutes, despite being only semi-aquatic.

“We found that semi-aquatic anoles exhale air into a bubble that clings to their skin,” said lead author Chris Boccia, who completed the work while studying at the University of Toronto but is now based at Queen’s University. “The lizards then re-inhale the air, a manoeuvre we’ve termed ‘rebreathing’ after the scuba-diving technology.”

The researchers found that all of the anoles they sampled had hydrophobic skin, meaning it repels water. They believe that this could’ve allowed them to evolve the ‘scuba-diving’ ability, as their hydrophobic skin causes a thin film of air to form on the body.

Using an oxygen sensor positioned inside the rebreathed bubble, they found that the oxygen concentration decreased during the dive, suggesting the lizards were using it up.

The researchers are now planning future projects to further understand the evolution of the physiology and behaviour related to the anoles’ rebreathing ability.

“The finding that different species of semi-aquatic anoles have evolutionarily converged to extract oxygen from their rebreathed air bubbles leads to other exciting questions,” said Lindsey Swierk, assistant research professor of biological sciences at Binghamton University. “For example, the rate of oxygen consumption from the bubble decreases the longer an anole dives, which could possibly be explained by a reduction in an anole’s metabolic rate with increased dive time. Anoles are a remarkable group of lizards, and the number of ways that this taxon has diversified to take advantage of their environments is mind-boggling.”

In numbers

830 km

The average distance travelled per day by a swift that was tracked during its migration by researchers at Lund University in Sweden.

50 billion

The number of wild birds estimated to exist on Earth, according to a citizen science project run by the University of New South Wales. That’s six birds for every human.

4,320 km²

The size of an iceberg observed breaking off Antarctica’s Ronne Ice Shelf by ESA satellites.

LINDSEY SWIERK, ESO/VLT

The interstellar 2I/Borisov comet, imaged here by the Very Large Telescope, has heavy metals in its atmosphere

SPACE

Heavy metals unexpectedly found in comets' atmospheres

Iron and nickel vapours in comets' atmospheres reveal a hole in our understanding of early Solar System

Astronomers have found traces of heavy metals in the atmospheres of all of the comets they have studied over the last 20 years – including 2I/Borisov, the first comet to visit from another solar system.

Heavy metals like iron and nickel are often found in comets, but only in their dusty and rocky interiors. However, solid metals usually don't sublimate – turn from solid directly to gas – at the low temperatures found in the atmospheres of distant comets. Heavy metals as gases had only previously been observed in much hotter environments, such as evaporating comets as they passed by the Sun, or in the atmospheres of ultra-hot exoplanets.

Belgian scientists were therefore surprised to find trace amounts of the two heavy metals in comet atmospheres throughout the Solar System, including those more than three times further from the Sun than the Earth's orbit.

Jean Manfroid, from the University of Liège, Belgium, led the study on Solar System comets, which was published in *Nature*. "It was a big surprise to detect iron and nickel atoms in the atmosphere of all the comets we have observed in the last two decades, about 20 of them, and even in ones far from the Sun in the cold space environment," he said.

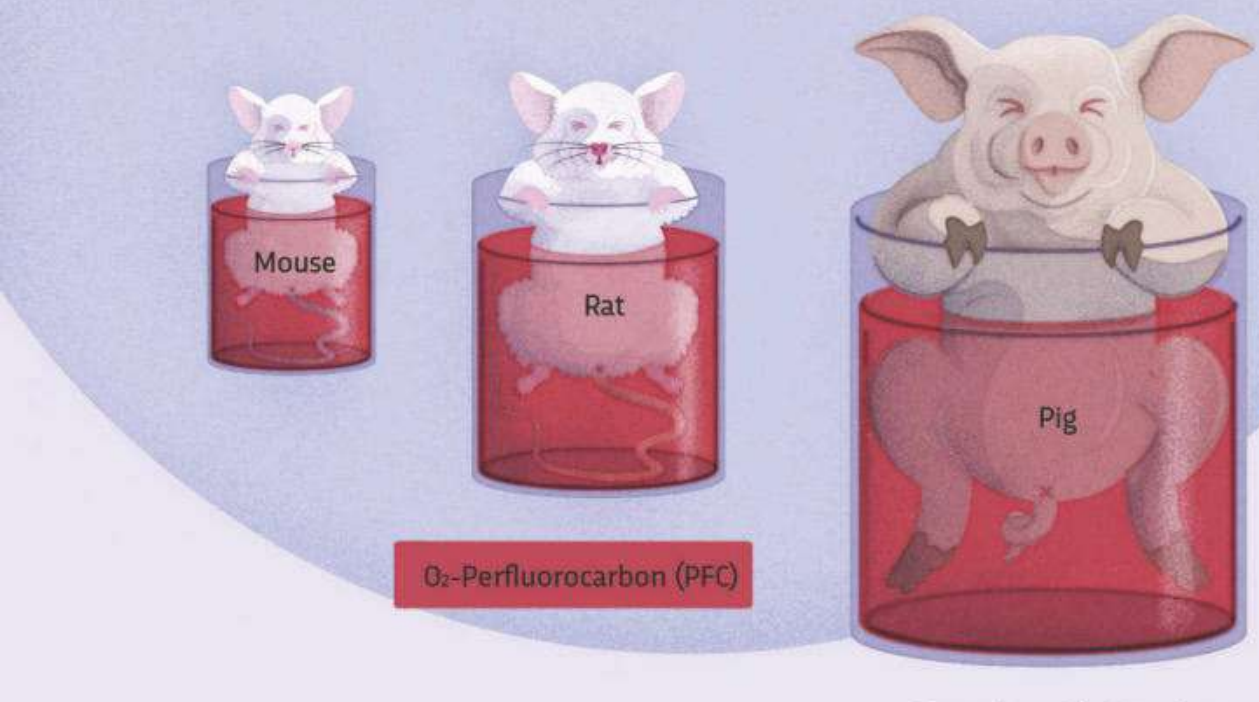
Usually, material from our Solar System contains about 10 times more iron than nickel. However, these comets had roughly equal amounts of iron and nickel.

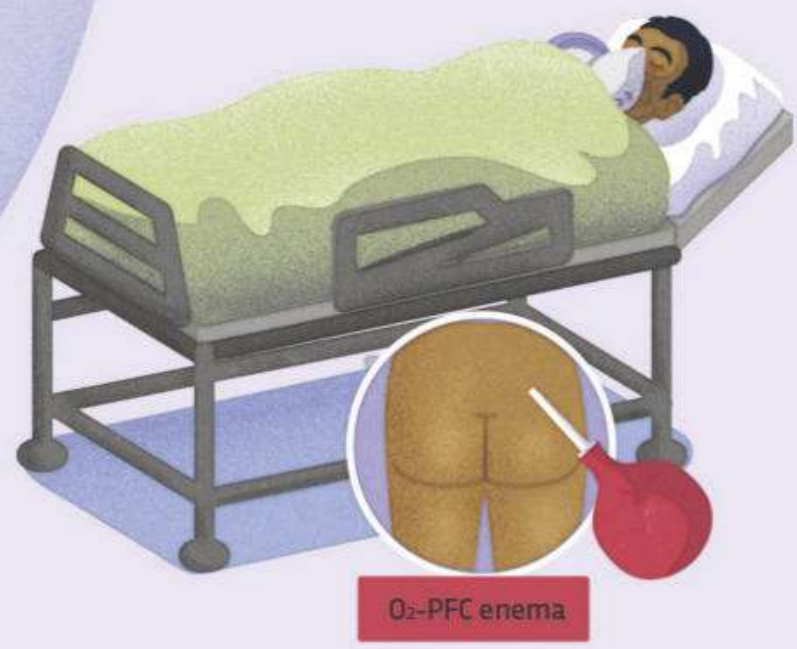
"We came to the conclusion they might come from a special kind of material on the surface of the comet nucleus, sublimating at a rather low temperature and releasing iron and nickel in about the same proportions," said Damien Hutsemékers, also a member of the team from the University of Liège.

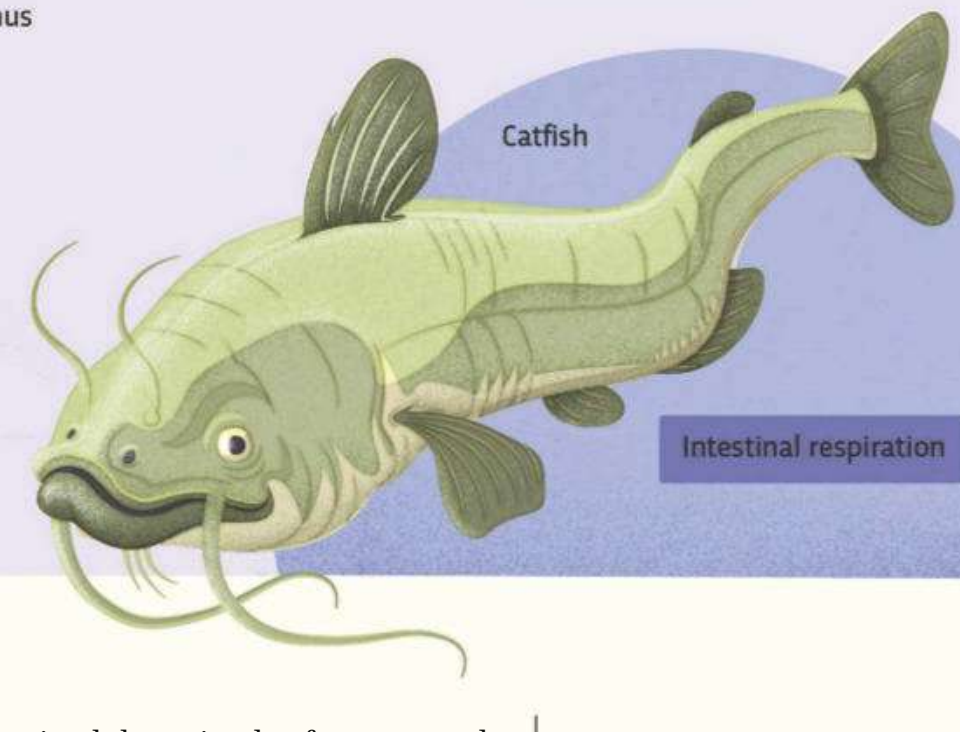
Since comets formed so early in the lifetime of the Solar System, the researchers say they are like "fossils for astronomers". So, these discoveries suggest that there is a hole in our understanding of early Solar System.

The scientists hope that future research with the upcoming Extremely Large Telescope can help to answer some of these questions, including what the material on the surface of the comet nucleus might be.

A second paper, published by a Polish team, describes the discovery of nickel in the atmosphere of 2I/Borisov. "At first we had a hard time believing that atomic nickel could really be present in 2I/Borisov that far from the Sun. It took numerous tests and checks before we could finally convince ourselves," said study author Piotr Guzik from the Jagiellonian University in Poland.







MEDICINE

You may be about to breathe through your bum, and one day it could save your life

Japanese scientists have discovered that some mammals can breathe through their anuses, opening a back door for a new type of treatment for patients with respiratory failure

For many animals, respiration involves breathing in oxygen and breathing out carbon dioxide via lungs or gills. However, there are several exceptions. Loaches, catfish and orb-weaving spiders can breathe through their guts when the supply of oxygen in their environment gets scarce.

Now, researchers at Tokyo Medical and Dental University (TMDU) have shown that oxygen can be delivered into the bloodstreams of mice, rats and pigs via their anuses. The technique, known as enteral ventilation, or EVA, could one day be used to help human patients with severe respiratory conditions.

"The rectum has a mesh of fine blood vessels just beneath the surface of its lining, which means that drugs administered through the anus are readily absorbed into the bloodstream," said first author Ryo Okabe. "This made us wonder whether oxygen could also be delivered into the bloodstream in the same way. We used experimental models of respiratory failure in mice, pigs and rats to try out two methods: delivering oxygen into the rectum in gas form and infusing an oxygen-rich liquid via the same route."

The researchers deprived the animals of oxygen and then administered oxygen enemas, either in gas form or via perfluorocarbons (PFCs). PFCs are liquids that can absorb large amounts of oxygen and carbon dioxide and are often used as a blood substitute or to assist the ventilation of premature babies.

In both cases, oxygen in the animals' blood increased, enabling them to survive for longer periods. The team also found elevated oxygenation in the cells.

"Patients in respiratory distress can have their oxygen supply supported by this method to reduce the negative effects of oxygen deprivation while the underlying condition is being treated," said co-author Prof Takanori Takebe. "Enteral ventilation showed great promise in our asphyxia-like experimental model. The next steps will be to test safety of the EVA approach with more profound mechanistic understanding by which it works; and to establish effectiveness in humans in a clinical setting."

"Drugs administered through the anus are readily absorbed into the bloodstream"

THE MENDJAN LAB ILLUSTRATIONS: KYLE SMART, DANIEL BRIGHT

BIOLOGY

Scientists have grown mini hearts that beat

The new heart models – each about the size of a sesame seed – were created using 'self-organising' cells

Here's news that should get your blood pumping: researchers from Vienna's Austrian Academy of Sciences have grown tiny, 3D heart-like organs in a Petri dish. Made from human stem cells, these sesame-seed-sized cardiac models even beat like the real thing.

Significantly, unlike previous versions of these tiny heart organs (called cardioids), the scientists didn't use artificial scaffolding to bind the cells together. Instead, the cells organised themselves to grow a hollow chamber.

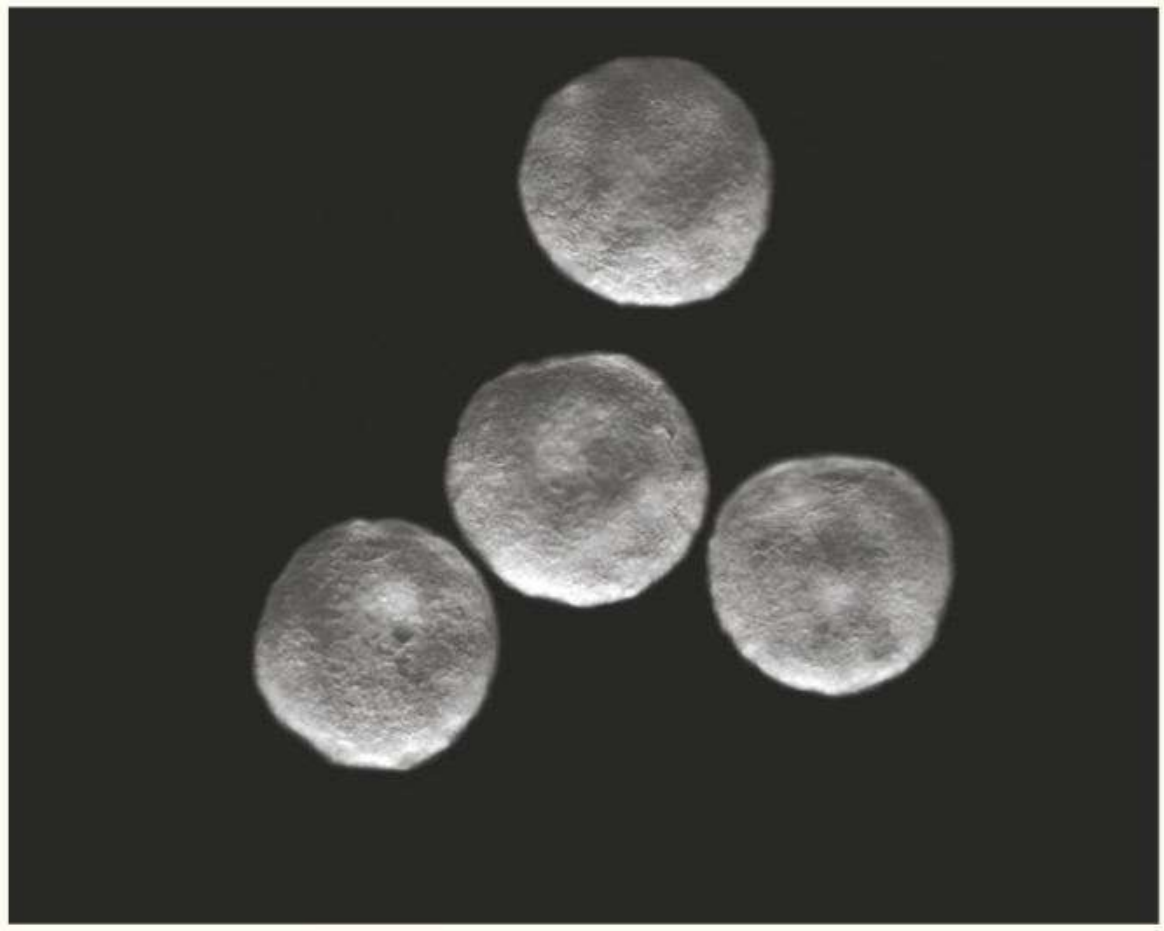
While useful to earlier studies, cardioids created with the old scaffolding technique did not show the same physiological responses to damage that a full-sized human heart does.

In an embryo, human organs develop from stem cells through a process called self-organisation. This is where cellular building blocks interact with each other, move and change shape until an organic structure emerges. The scientists in Vienna replicated this process by activating signalling pathways in the stem cells. After one week of development, a hollow organoid grew that contracted rhythmically and was able to squeeze liquid around its cavity.

"Self-organisation is how nature makes snowflake crystals or birds behave in a flock. This is difficult to engineer because there seems to be no plan, but still something very ordered and robust comes out," said lead researcher Dr Sasha Mendjan.

"The self-organisation of organs is much more dynamic, and a lot is going on that we do not understand. We think that this 'hidden magic' of development, the stuff we do not yet know about, is the reason why currently diseases are not modelled very well. We want to come up with human heart models that develop more naturally and are therefore predictive of disease," Mendjan added.

The scientists already have plans to grow cardioids with multiple chambers to improve our understanding of how heart defects develop in foetuses.



The tiny cardioids are able to beat like a real heart

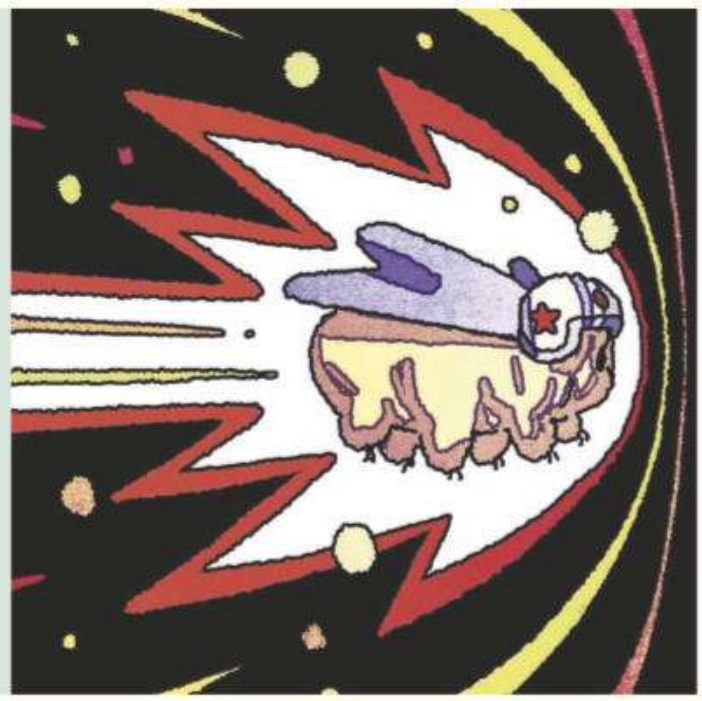
They did what?

Tardigrades fired out of a cannon

WHAT DID THEY DO?
Researchers at the University of Kent took 20 tardigrades, put them into a state of hibernation by freezing them, placed them inside water-filled nylon cylinders, and then fired them at sand targets at breakneck speeds using a high-powered light gas gun.

WHY DID THEY DO THAT?
The team wanted to know if the tardigrades, which are the only currently known animal capable of surviving in outer space, could potentially endure a trip across the cosmos on an asteroid or comet, and seed life on another planet – a theory known as panspermia.

WHAT DID THEY FIND?
The tardigrades were unable to survive being shot at speeds higher than 900 metres per second, slightly less than the speed of 1,100 metres per second reached by a typical meteorite that collides with Earth. This means that tardigrades, or other organisms similar to them, are unlikely to be responsible for the interplanetary seeding of life.



MEDICINE

Reading stories to children in hospital helps relieve their pain and stress

All the children in a Brazilian study had increased levels of oxytocin after listening to stories

Many children's hospitals already have storytelling programmes that aim to cheer up patients. But new research, published in the journal *Proceedings Of The National Academy Of Sciences*, suggests that storytelling also has physiological benefits.

"Until now, the positive evidence for storytelling was based on 'common sense' and taken at face value, in which interacting with the child may distract, entertain and alleviate psychological suffering," said study co-author Dr Jorge Moll, of D'Or Institute for Research and Education (IDOR), Brazil. "But there was a lack of a solid scientific basis, especially with regard to underlying physiological mechanisms."

The team, based at IDOR and the Federal University of ABC, Brazil, studied 81 children between the ages of two and seven, all of whom were in the intensive care unit at Rede D'Or São Luiz Jabaquara Hospital in São Paulo. A group of 41 children each had a session with a storyteller, lasting 25 to 30 minutes. A control group of 40 children each had the same amount of time with the same professionals, but they told riddles instead.

Before and after the sessions, the team took saliva samples from each child and assessed their pain level. The saliva samples allowed the researchers to measure levels of the hormone cortisol, which is related to stress, and the hormone oxytocin, which plays a role in empathy.

Both groups of children benefitted from the sessions: they all had less cortisol and more oxytocin in their saliva, suggesting they were less stressed, and they reported less pain and discomfort. However, the results were twice as strong for the storytelling group than the control group.

At the end of the sessions, the children also took part in a word-association exercise, which included words like 'hospital', 'nurse' and 'doctor'. The team said that while children from the control group responded to the image of a hospital with "this is the place that people go when they are sick", the storytelling group responded with "this is the place that people go to get better".

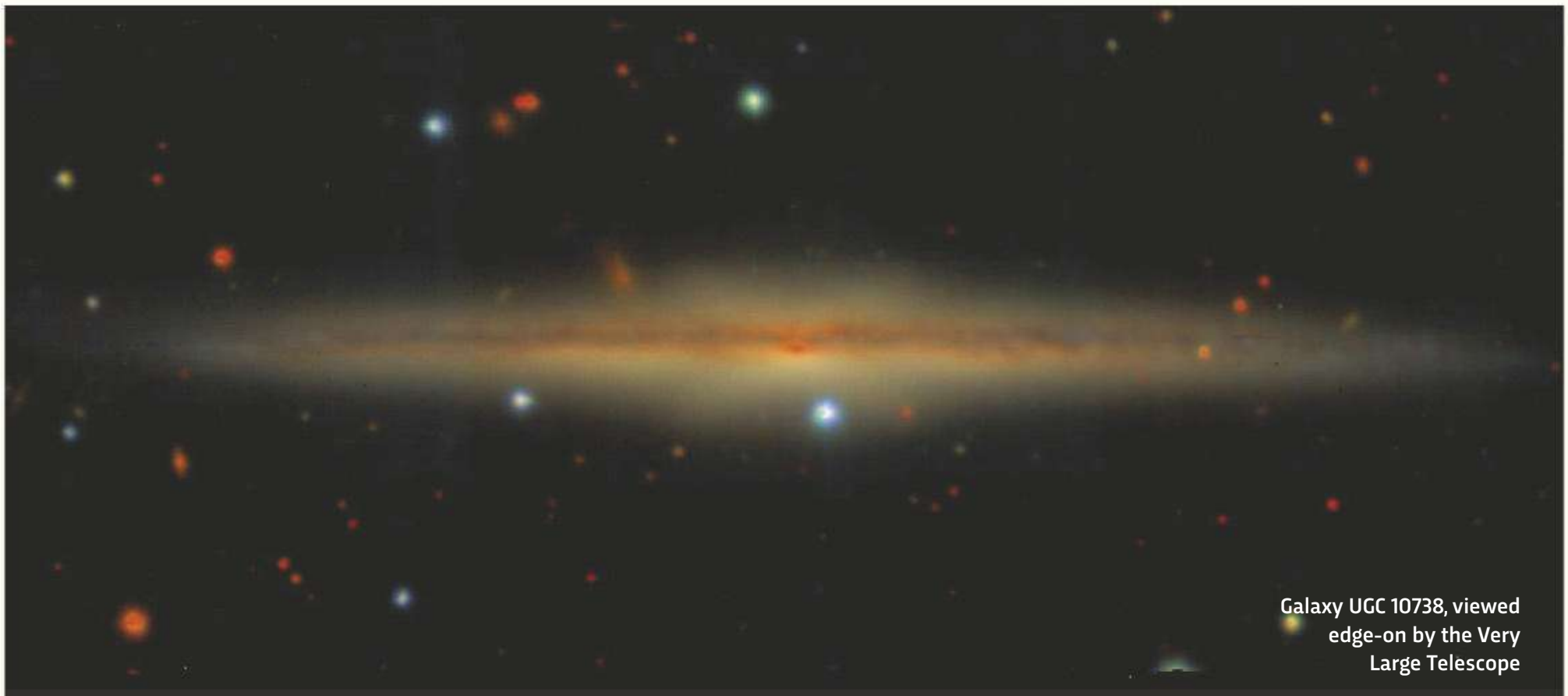
Similarly, children from the control group said "this is the bad woman who comes to give me an injection" in response to a doctor or nurse, whereas the storytelling group said "this is the woman who comes to heal me".

"I consider this study to be one of the most important I have participated in, due to its simplicity, rigour, and potential direct impact on practices in the hospital environment, aiming at the relief of human suffering," said Moll.

"As it is a low-cost and highly safe intervention, it can potentially be implemented in the entire public system, once larger scale studies verify its reproducibility and effectiveness. We intend to extend and replicate it in other settings and patient groups and to support volunteering dedicated to the noble activity of storytelling, now with more solid scientific evidence," he added.

Storytelling is a low-cost intervention that could improve the wellbeing of hospitalised children

GETTY IMAGES, JESSE VAN DE SANDE/EUROPEAN SOUTHERN OBSERVATORY



Galaxy UGC 10738, viewed edge-on by the Very Large Telescope

SPACE

Sorry, the Milky Way isn't as cool as we thought it was

But a new discovery could be a game-changer, both for the history of the Galaxy and the future of astronomy

Bad news for anyone who thought the Galaxy was one of the cool, hip neighbourhoods of the Universe: new research by Australian scientists suggests the Milky Way is far more normal than astronomers had previously thought.

For the first time, a galaxy similar to our own was studied in detailed cross-section. The galaxy's structure, according to the team from the University of Sydney, is a lot like the Milky Way, which forces us to reconsider what we know about our own cosmic neighbourhood.

The spiral structure of the Milky Way consists of two layers of stars, one thick and one thin. The thick layer features mainly ancient stars with a lower ratio of iron to hydrogen and helium. The thin layer, which includes the Sun, is home to younger stars that are more metallic. Until now, researchers had assumed these layers were the result of a freak and violent accident millions of years ago: a collision between two very different galaxies. However, the newly studied galaxy – dubbed UGC 10738 – reveals that it too has a similar structure.

"Our observations indicate that the Milky Way's thin and thick discs didn't come about because of a gigantic mash-up, but a sort of 'default' path of galaxy formation and evolution," said Dr Nicholas Scott, one of the lead scientists of the study. "From these results we think galaxies with the Milky Way's particular structures and properties could be described as the 'normal' ones."

Far from being galactic hipsters with mysterious backstories, Milky Way-style galaxies are probably extremely common. But if that sounds like an anticlimax, think again: it's a potential leap forward in astronomy.

"It means we can use existing, very detailed observations of the Milky Way as tools to better analyse much more distant galaxies which, for obvious reasons, we can't see as well," said Scott.

Although astronomers have viewed similar discs in other galaxies, they have never been able to analyse the type of stars that exist within them.

Scott and his colleagues solved this issue by pointing the European Southern Observatory's Very Large Telescope in Chile at UGC 10738, located 320 million light-years away. Relative to Earth, the galaxy is viewed 'edge on', revealing a cross-section of its structure.

"Using an instrument called the multi-unit spectroscopic explorer, or MUSE, we were able to assess the metal ratios of the stars in its thick and thin discs," said study co-lead Dr Jesse van de Sande, from the Sydney Institute of Astronomy in Australia. "They were pretty much the same as those in the Milky Way – ancient stars in the thick disc, younger stars in the thin one. We're looking at some other galaxies to make sure, but that's pretty strong evidence that the two galaxies evolved in the same way."

It's an important step forward in our understanding of how galaxies evolved, said co-author Prof Ken Freeman from the Australian National University. "We know a lot about how the Milky Way formed, but there was always the worry that the Milky Way is not a typical spiral galaxy. Now we can see that the Milky Way's formation is fairly typical of how other disc galaxies were assembled."

ZOOLOGY

Billions of ‘Brood X’ cicadas emerge after 17 years underground to get jiggy with it

Billions of periodical cicadas emerged from the ground in early June across 15 states in the US, from Georgia in the south to New York in the north. The insects spend most of their lives as nymphs living less than a metre beneath the surface, feeding on sap from tree roots. Then after either 13 or 17 years, depending on the species, they emerge in vast numbers for a brief adult stage, mate and die.

There are 15 ‘broods’ in total, which are grouped according to the year in which they emerge. Brood X consists of all three 17-year species, and is the largest and most impressive cicada emergence.

So why do they emerge every 17 years? “For a long time the explanation was that the prime-numbered 17-year cycle, and the 13-year cycle of some other periodical cicada broods, prevented predators getting into phase with them by having a life cycle that was a divisor – prime numbers having no divisors,” said Prof Adam Hart, an entomologist at the University of Gloucestershire. “But the current thinking is that it prevents hybridisation between broods with different cycles and mathematical models back this up.”

1

2

GETTY IMAGES X3, SHUTTERSTOCK X2

3

4

1. The cicada nymphs emerge after sunset and crawl to a nearby tree, plant or bush. At this stage of their life cycles, they are pale brown and wingless. Shortly after emerging, the nymphs begin the process of moulting their exoskeletons and entering adulthood.

2. Following the moulting, countless discarded exoskeletons can be found all over the area where the cicadas emerged. When insects moult, they also shed the linings of their trachea, which are used for breathing. These can be seen as white threads in this image.

3. Cicadas have five eyes – two distinctive red compound eyes and three much smaller ocelli located in the centre of their heads, which are believed to detect light and dark.

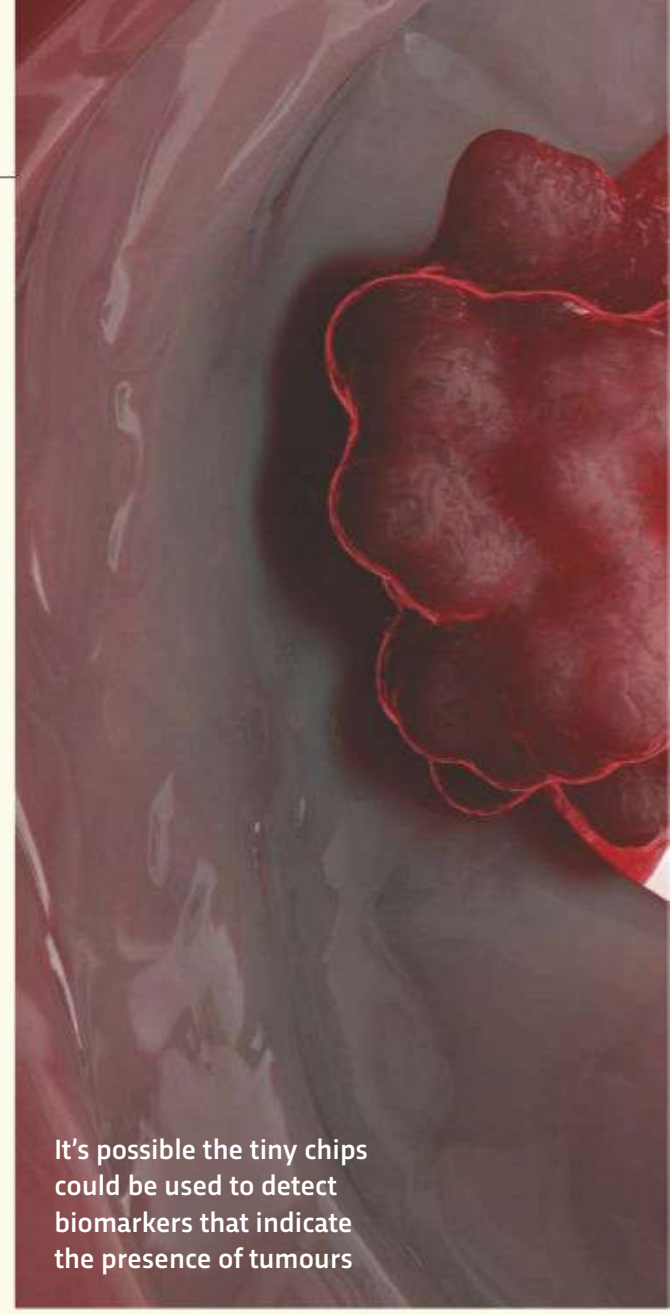
4. Males use a special organ on their abdomen called a 'tymbal' to produce their characteristic screeching sound. They do this to attract females to mate with. Cicadas can mate multiple times, and a single female may lay as many as 600 eggs. Once the eggs hatch, the nymphs burrow into the ground to begin the entire cycle all over again.

PROF KEN SHEPARD
Electrical and biomedical engineer

Horizons

Tiny chips use ultrasound to monitor your body... from the inside

Engineers at Columbia University have developed a single-chip medical device so small it can be injected into patients using a hypodermic needle



It's possible the tiny chips could be used to detect biomarkers that indicate the presence of tumours

WHAT'S THE BACKGROUND TO THIS RESEARCH?

Moore's Law states that you can cram more and more transistors into a certain area on an integrated circuit chip. And that number's been growing exponentially for the last 30 or 40 years. It's primarily been used not to make the chips smaller, but to put more transistors on a chip that's the same size. So, we've gone from chips with a thousand transistors to chips with tens of billions. But another thing you could do with that density is use it to make chips that are very, very small.

HOW SMALL ARE WE TALKING?

So this is the smallest autonomous single chip system that we know of that supports both power and bidirectional communication – it's roughly 300 x 300 microns [one micron = 0.001mm].

WHAT ARE THE MAIN CHALLENGES OF PRODUCING A CHIP THIS TINY?

A chip needs to be powered and you need to be able to communicate with it, otherwise it's of no use. So what we've been doing is an example of a device where the chip is the entire system. There's nothing else; no external sensor array, no external antenna, no external battery, there's no external anything. And for a chip to operate as an autonomous system, it needs to meet a few criteria. All of the power and communication to the chip needs to be done wirelessly. So, all the antennae for that wireless powering and communication need to be integrated. And then in the case of these kind of implantables, the chip is also sensing something, so that sensing function has to be integrated.

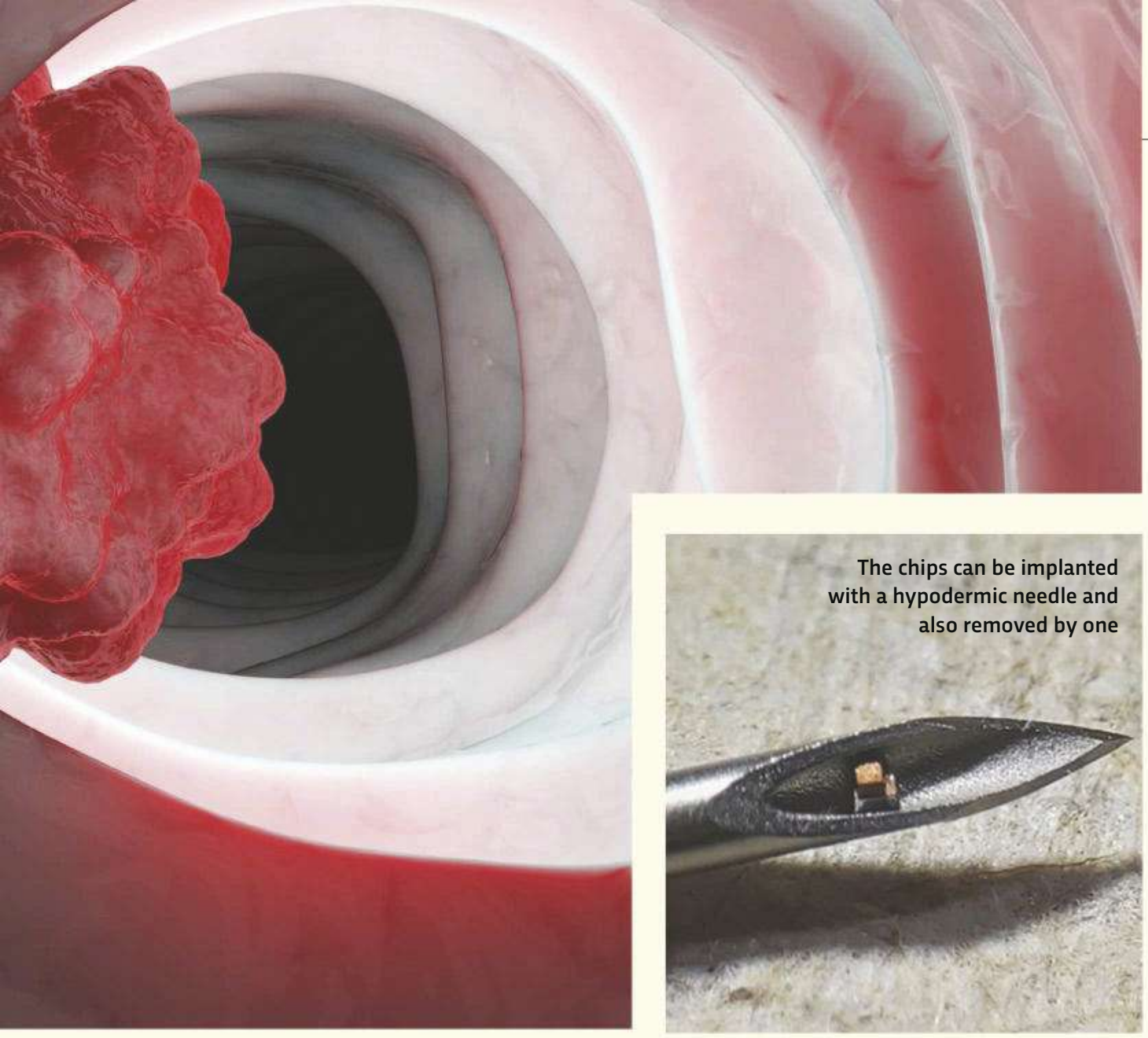
You'd be very challenged to communicate with a device this small with electromagnetics, such as radio waves, because the wavelength is too large relative to the size of the device. Even at tens of gigahertz, you're talking about wavelengths in the several millimetre range. This device is much less than a millimetre in size, so that's why we use ultrasound. This device is powered and communicates with acoustics, not electromagnetics, which is useful because sound waves travel very well in the body.

HOW EXACTLY DO YOU POWER THE CHIP WITH ULTRASOUND?

We're looking at using these devices to augment ultrasonography, to provide additional information that's not intrinsically available. The way ultrasound works is that it sends a sound wave into your body. And when there's an acoustic mismatch, a difference in the acoustic impedance

"So what you see is this tiny chip in your ultrasound image flashing at you. And that flashing is sending information back to you that tells you what it measured locally"

GETTY IMAGES, CHEN SHI/COLUMBIA ENGINEERING



The chips can be implanted with a hypodermic needle and also removed by one

[the amount of resistance an ultrasound beam encounters as it passes through tissue] due to different materials or interfaces in your body, that reflects some of that acoustic energy back to the imager. And that's what you see in an ultrasound image.

But there are many things that aren't available or known to you. For example, this particular chip [we've designed] measures temperature. There's no way in intrinsic ultrasound imaging that I can know anything about temperature. If I put one of these devices in your body and the ultrasound beam hits it, the energy turns the device on, which then measures the local temperature and modulates the reflected energy back to the ultrasound imager accordingly. So what you see is this tiny chip in your ultrasound image flashing at you. And that flashing is sending information back to you that tells you what it measured locally.

The chip also does something called 'energy harvesting' – it harvests the energy from the ultrasound beam. And it can do that because we've integrated a piezoelectric material into the chip that converts sound to electricity. So, when you apply a pressure wave to this material – which is what sound is, a pressure wave – the material gets squeezed a little bit, which generates a voltage. That voltage is used to power the chip.

HOW DEEPLY CAN YOU IMPLANT THE CHIP INTO THE BODY?

We're using about 5MHz ultrasound for these devices. Most clinical ultrasound is a little lower frequency, usually about a 1MHz or so. As you go up in frequency, you can penetrate less deeply as the ultrasound is absorbed more in your tissue. But at 1MHz, the wavelengths are too large to communicate with this device. So, at 5MHz, we can go about maybe six or seven centimetres deep, which is pretty substantial.

HOW DO YOU PLACE THEM INSIDE THE BODY?

The chips are small enough to fit in an 18-gauge hypodermic needle, so that's how we inject them into the body. They can also be removed in the same way.

HOW DO THEY FUNCTION ONCE THEY'RE IN?

There are two ways the devices could be used. One is where it's chronically implanted – you simply put it in and leave it alone. But much more testing has to be done to understand the long-term consequences of having something like that in your body. The belief is that being so small will help it to be acceptable and so there'll be less of a foreign body response. The other way would be that you simply remove it after a period of time. And you can do that using the same kind of hypodermic needle, but guided with ultrasound. You use the ultrasound imager to guide the needle, find the device and then suck it out.

WHAT ARE THE POTENTIAL APPLICATIONS?

Our particular design provides additional information to an ultrasound imager. And that can be used in almost any context in which you're doing ultrasound imaging. For example, there are many clinical applications in which clinicians apply heat. So, if you wanted to know how much heat you're applying, you could use the chip that measures temperature. There also might be specific biomarkers that you're looking for, maybe you're doing continuous ultrasound imaging over time to verify that a tumour hasn't come back. But it might make sense to implant devices like this that measure biomarkers to indicate even earlier if there's a concern. We're also looking at trying to improve healing by monitoring various biomarkers within a wound.

WHAT ARE THE NEXT STEPS?

Well, there are lots of other things you could do with these 'chip as a system' implants. There's a lot of interest right now in interfaces to the central nervous system – brain/computer interfaces and devices that interface with the peripheral nervous system for things like pain management, and interactions with the autonomic nervous system to control things like blood pressure.

What these devices are delivering is what we call 'volumetric efficiency', a statement of how much function you're able to get out of the implantable device for a given amount of displaced volume. These devices are the most volumetrically efficient devices you can imagine, because you can get the maximum amount of function out of these devices for a minimum amount of displaced volume. And that gives them a lot of advantages.

PROF KEN SHEPARD
Ken is the Lau Family Professor of Electrical Engineering at Columbia University in the City of New York.

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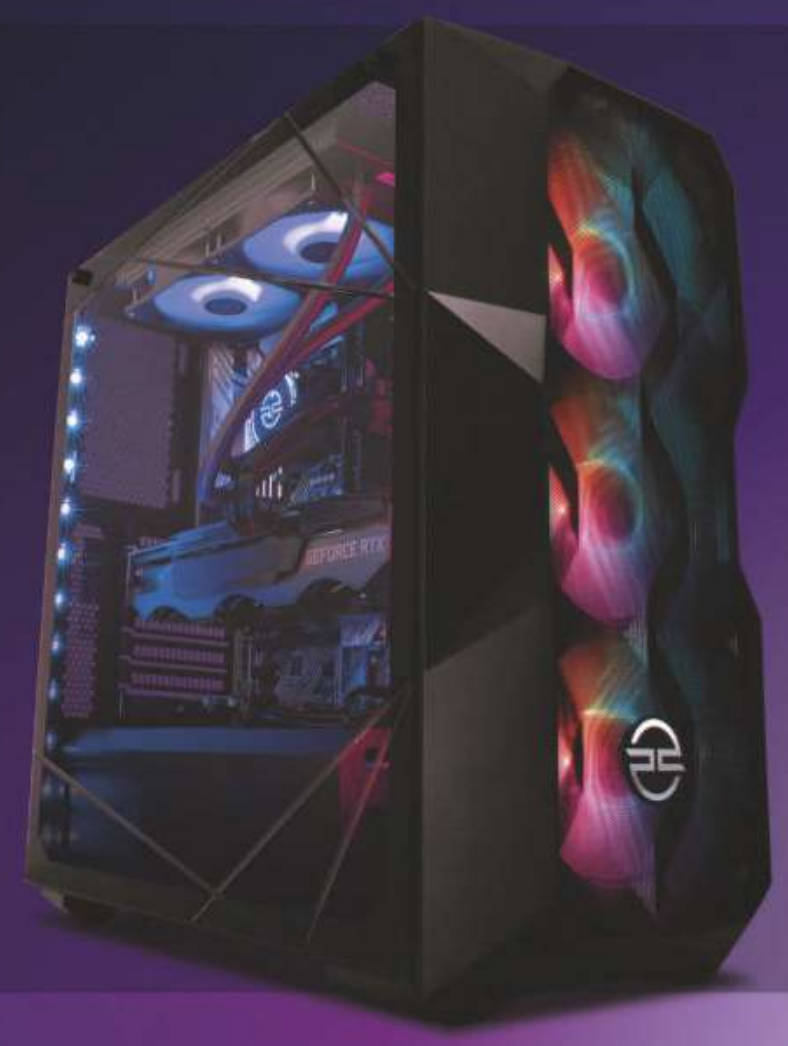

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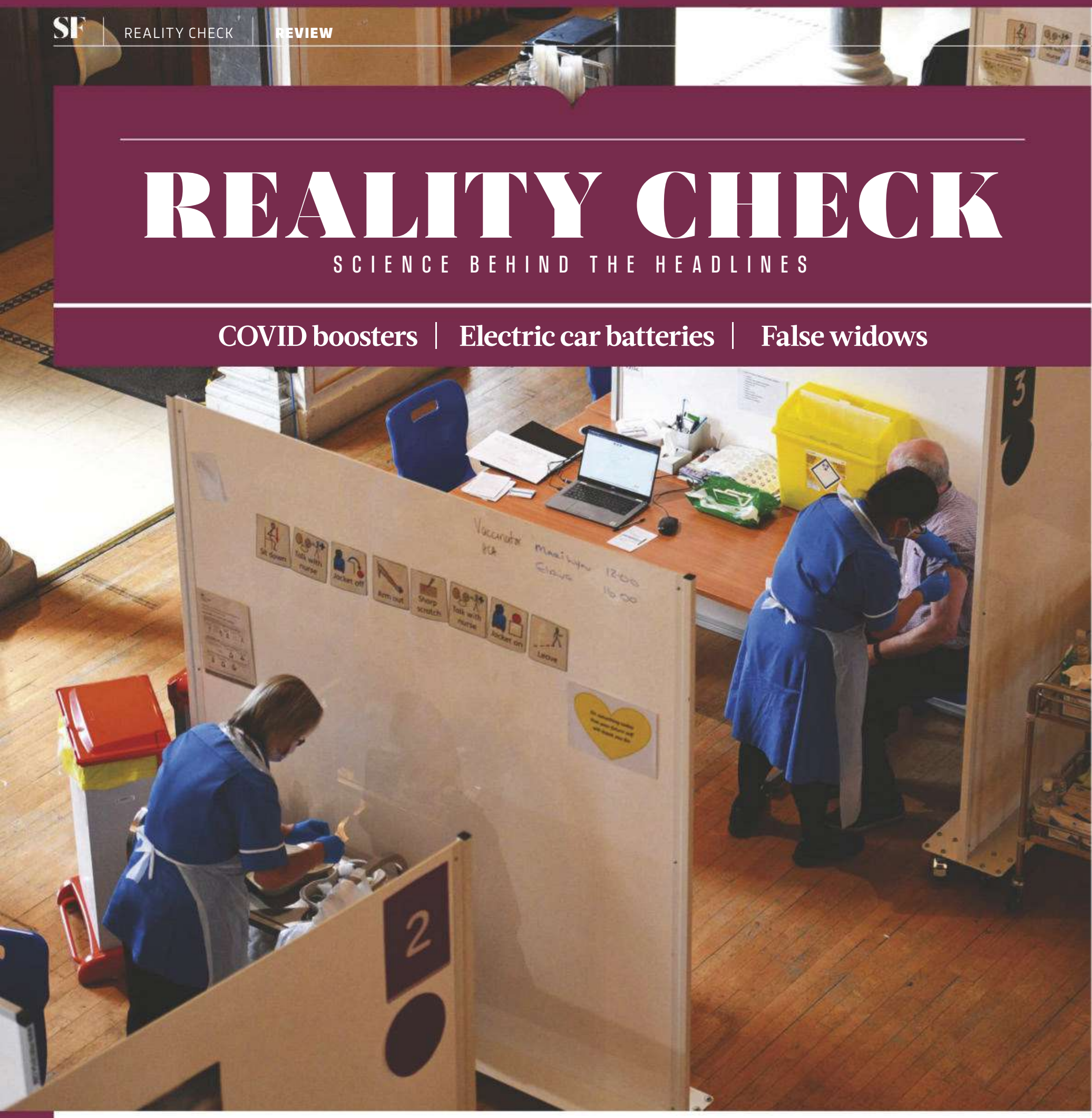

REVIEW

COVID BOOSTERS: WILL WE NEED THEM TO PROTECT US AGAINST FUTURE VARIANTS?

As the population continues to be vaccinated against the coronavirus, scientists are starting to investigate whether we'll need annual boosters to keep it at bay

"It is too early to know how long the COVID-19 vaccine immunity lasts, but there is good evidence that immunity will continue for at least six months for most people"

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The UK has recently initiated one of the first studies evaluating COVID-19 booster shots. The study, led by the University Hospital Southampton NHS Foundation Trust, will look at how safe and effective booster jabs are when given to people at least three months after their normal two-dose COVID-19 vaccinations. The study will also look at mixing and matching vaccine types (for example, someone who was originally vaccinated with two doses of AstraZeneca might be given a booster from Pfizer). It may seem premature to start evaluating booster jabs when only 45 per cent of the population has been fully vaccinated (as of 26 May); however, the clinical trials needed to validate the booster jabs will take several months to complete. By starting now, we can ensure that the boosters are ready and available when we need them.

WHY MIGHT WE NEED BOOSTER JABS?

The concept of a booster jab is to increase COVID-19 immunity in the event that our immune system is no longer able to effectively recognise and stop the virus. There are two cases in which a booster jab may be necessary. The first is if our vaccine-induced immunity declines over time. For some vaccines, the level of protection slowly decreases over time until we are no longer protected from infection (for example, cholera vaccines need to be boosted every 6-24 months).

Other vaccines (such as the measles vaccine) induce lifelong immunity. It is too early to know how long the COVID-19 vaccine immunity lasts, but there is good evidence that immunity will continue for at least six months for most people.

WILL THE BOOSTERS PROTECT US FROM NEW VARIANTS?

Regardless of how long the vaccine protection lasts, it is possible that the virus will change enough that the vaccines don't work as well. We have already seen that some of the new COVID-19 variants are able to evade some of the vaccine-induced protection, and infections of fully vaccinated people are being reported. At present this is still a low rate of breakthrough infections, but as long as the virus continues to circulate around the world, it will continue to mutate, potentially resulting in variants that can more completely evade the immune system. Thus, we also may need a booster jab to compensate for new variants. This is similar to what occurs with the flu jab where the virus changes enough every year that the vaccines can no longer protect against infection, requiring a new jab every year.

WILL BOOSTER SHOTS HAVE TO BE THE SAME TYPE (PFIZER, ASTRAZENECA, ETC) AS THE PREVIOUS DOSES?

The booster jabs may end up being the same vaccine type used originally or a different type (for example, a Pfizer booster after originally receiving AstraZeneca). The ongoing study will establish if it is safe to mix and match. If the ➤

GETTY IMAGES X2

BELOW The current vaccines are effective against the coronavirus, but new strains may mean that subsequent boosters need to be slightly reformulated

booster is solely given to increase immunity that has faded over time, then the vaccine may be very similar to the original vaccine used. However, if the booster is designed to address a new variant, then the vaccine formulation will likely be slightly different so that it can now protect against these forms of the virus. This updated formulation may offer protection against more variants that the current vaccines do, but it will not be future-proof. It is possible that someday we will have a universal COVID-19 vaccine that will protect against any variant; however, this is likely a long way off (for comparison, we still do not have a universal flu vaccine).

WHO WILL GET THE BOOSTERS FIRST?

All of these boosters will be carefully evaluated through clinical trials in order to demonstrate that the boosters are safe and effective for different age groups. This includes evaluating any new vaccine formulation as well as looking at how well the vaccines work if you have a booster from a different manufacturer than you were originally vaccinated with. This will ensure that when boosters become available, we know they are safe. Still, it is not certain who would be first to receive the booster jabs. It would likely be the groups at highest risk of COVID-19 infections or serious illness, and possibly the age groups whose immunity wanes the fastest, though the goal would likely be to eventually vaccinate the entire population with the boosters. It is possible that we'll get to the point where we need booster jabs in a matter of months from now, or it's possible that we never need boosters. However, as long as there is continued circulation of COVID-19 around the world, the likelihood of a vaccine-evading variant is high. This is why we need to ensure that we are evaluating booster vaccines for the future, while also striving to eliminate virus transmission worldwide.

by **DR JEREMY ROSSMAN**

Jeremy is an honorary senior lecturer in virology and president of Research-Aid Networks, University of Kent. His research focuses on the process of infectious disease outbreaks.

ANALYSIS

ELECTRIC VEHICLES: WHAT CAN WE DO WITH THE GROWING NUMBER OF DEAD BATTERIES?

What will happen to the batteries when the first generation of electric vehicles reach the end of their lifespans in around a decade? Are they bound for the scrapheap, or can they be salvaged?

Combustion-engine vehicles are viewed as enemies of the environment and it's easy to see why. By burning fossil fuels, every motorcycle, car, van and lorry adds to air pollution and contributes to climate change. It's why governments are encouraging drivers to switch to more environmentally friendly electric vehicles

REUTERS PICTURES

ABOVE A technician at a recycling factory checks for possible remaining voltage in a burned-out lithium-ion battery

(EVs). But while combustion-engine vehicles are an enemy in terms of emissions, they're currently more of an ally when it comes to recycling.

The lead-acid batteries found in combustion-engine cars are easily and widely recycled, says Dr Daniel Reed, a lecturer in materials chemistry at the University of Birmingham. "Lead-acid batteries are the most recycled consumer product globally. [The technology is] mature and standardised so it doesn't matter who makes your battery or which car you own because the battery conforms to certain regulatory specifications."

The simplicity of lead-acid batteries also helps. They contain relatively few materials (lead for the electrodes, sulphuric acid for the electrolyte, and polypropylene to encase everything), each of which can be easily separated and sold.

The lithium-ion batteries used in EVs are almost the exact opposite.

"In a lithium-ion battery, you've got about 10 different components that are interspersed as tiny composite materials, as well as fluorinated polymers, fluorinated electrolytes and fluorinated solvents, all which are a complete nightmare to separate,"

"There's a need for a degree of legislation to compel manufacturers to make sure these batteries are recycled"

says Prof Andrew Abbott, a physical chemist at the University of Leicester.

Many of those materials are toxic and some are pyrophoric, so may ignite if they come into contact with air, which makes breaking EV batteries down a complicated and costly process.

The other issue is that a lot of the materials in lithium-ion batteries are 'critical metals' (rare-earths, lithium and cobalt, for example), which are vital for making the switch to clean-energy technology but are found in just a few countries. So, the only way to ensure a lasting supply is to recover them from the products they're used to make.

It therefore seems as if we're facing further problems by switching to EVs. But it's not all bad news.

First, EV batteries can be reused. Once they reach a point where they're no longer able to power a vehicle, they can have a second life as storage devices for energy generated from renewable sources.

Second, it is possible to recycle EV batteries, it's just complicated and, for the time being, not cost effective. But that's set to change.

Due to improving battery performance and measures like carbon taxes, it's estimated we'll reach price parity for combustion-engine vehicles and EVs by 2023. "[At that point] we'll see a big change in terms of adoption," says Abbott. "The lifetime of the batteries in these vehicles is estimated to be in excess of 10 years. So, in around 15 years the UK will probably be at a point where it has about half a million EVs a year that need recycling."

By then, the market for EV batteries is expected to be 10 times the size of the current lead-acid battery market (based on the greater size of EV batteries and number of materials needed to make them, along with the declining number of combustion engine vehicles on the road), so there'll be plenty of incentive to find more cost-effective methods of recycling EV batteries in the intervening years. But while it's

A used lithium-ion battery is opened up prior to being dismantled at a recycling factory in Germany

in the interests of the manufacturers to ensure a supply of the necessary raw materials, it's going to take more than just market forces to fully address this issue.

"There's a need for a degree of legislation to compel manufacturers to make sure these batteries are recycled. The European Union has brought in legislation, which I believe the UK has copied," says Reed, while acknowledging that any legislation can't be too heavy-handed. "There needs to be freedom to innovate on recycling as well as battery manufacture. But the onus needs to be on recycling and recovering materials."

Innovation on battery manufacture is vital because the complexity and variety of designs is arguably the major obstacle to recycling. Part of the problem is the technology is still emerging – new battery designs are continually appearing, and committing to the wrong one could be disastrous for a battery or car manufacturer.

A simpler, standardised EV battery that's safe, easy and cheap to separate into its component parts is the solution everyone's looking for; in other words, the EV battery equivalent of the lead-acid battery. But it's worth remembering we've only had lithium-ion batteries since the 1980s. Lead-acid batteries appeared around 1860 and it wasn't until the 1970s that the design for motor vehicles was standardised.

"Standardisation will come in to some extent, but it's a chicken-and-egg situation," says Abbott. "[Recycling EV batteries] is a known problem and there are known solutions for it. It's just ramping production and recycling up at the same rate and marrying the two together."

—

by **ROB BANINO**

Rob is a freelance science and technology journalist and editor.

COMMENT

SPIDERS: SHOULD I BE WORRIED ABOUT BEING BITTEN BY A FALSE WIDOW?

A study has found that numbers of the spiders are increasing, along with the number of people being bitten. But what risk do they really pose?

You could be forgiven for thinking that the UK is in the grip of a spider emergency. With "spider numbers surging" and "dangerous bite warnings" being issued in the media, people are being "terrorised" and even hospitalised.

These headlines have been building for a few years, and the species behind the media arachnid obsession is the noble false widow spider, *Steatoda nobilis*.

A relative newcomer to the UK, the species is from the Canary Islands and Madeira. First reported from a site near Torquay in 1879, it spread through southern England, building up from the 1980s to become quite abundant, particularly in urban areas.

It has also been expanding its range northwards. So, although the lurid headlines are recent, the species has been around in many parts of the country for some time.

FANGS A LOT

If we want to get to the truth behind the headlines then there are several questions we need to answer. First, can noble false widows actually bite? There are not many UK species of spiders with fangs that are able to pierce our skin, but the noble false widow's fangs certainly can.

However, in common with most spiders, they are not aggressive. Bites seem to occur when spiders are trapped in clothing or when people are asleep and perhaps roll over, trapping a spider. It is little comfort for anyone who has been bitten, but it is important to keep in mind that these animals are not out to get us.

The second question we need to answer is, are bites getting more frequent? Given that the spiders are getting more abundant, and that they are found where people live, then this certainly seems likely.

It is also supported by evidence away from the headlines. The noble false widow has been increasing in Ireland, and a study was recently conducted at the National University of Ireland, Galway on their bites.

Aiste Vitkauskaite, an MSc student in toxicology and joint lead in the study, reported: "Approximately

ALAMY, NICK UPTON/NATUREPL.COM

"Bites seem to occur when spiders are trapped in clothing or when people are asleep and perhaps roll over, trapping a spider"

10 species of Irish spiders have fangs large enough to bite through human skin, yet over the past five years, we have never heard of anybody being bitten by any of the native species. Within the same period, we have recorded dozens of confirmed or probable false widow bites."

Vitkauskaite went on to confirm that: "These spiders will become increasingly common and so will their bites."

The final and perhaps most important question to answer is, are the bites medically significant? This is a challenging question to answer. It can be difficult to confirm that a bite has been caused by a spider at all, and if it has, which species was the culprit. The Ireland study bypassed species misidentification (and noble false widow spiders are easily confused with similar species) by using DNA extraction and genetic profiling.

This allowed them to confirm 'envenomation', when spider bites result in venom being injected, in 16 cases. Symptoms included debilitating pain, tremors, fatigue, nausea and low blood pressure. Bites were also able to cause bacterial infections, including cellulitis and dermatitis.

While many bites likely result in only mild symptoms, in some people bites can cause more severe reactions and, the study found, hospitalisation was required in some cases. The study warns that noble false widows may represent a potential threat to public health.

Although this new study shows that in some cases noble false widow bites can cause problems for humans, we need to keep things in perspective. No one has died as a consequence of spider venom in the UK, whereas around five people a year are killed by wasp and bee stings, and several people die annually from dog attacks. Spider bites seem to tap into our deepest fears, but remember that many of us have lived with, and will continue to live with, noble false widow spiders around our homes with no ill effects.

Indeed, I doubt most people are even aware of them. I have been sent many photographs of spiders thought to be noble false widows and very few actually have been. As with all risks, we should keep things in perspective and perhaps be grateful that the UK we have few animals that can do us any harm at all.

If you are unlucky enough to get bitten by a false widow spider, then don't panic. Try to get a photograph of the spider, or, if you can do so safely, capture it in a container for later identification. Just like with a bee sting, there may be some pain and swelling, but if you develop other symptoms, or the pain becomes more severe, then you should seek medical attention. **SF**

by **PROF ADAM HART**

Adam is an entomologist and the professor of science communication at the University of Gloucestershire. His latest book, Unfit For Purpose *(£16.99, Bloomsbury Sigma), is out now.*

THE SMART SPEAKER REVOLUTION

How the advent of voice assistants has heralded a huge step towards the smart home

Voice assistants like Alexa and Siri are fast becoming our new best friends. Smart devices using this voice recognition technology are helping us to live the good life. Rather than heaving yourself off the sofa to turn off the light, why not just ask Alexa to do it? Forgot to turn the heating down before leaving home this morning? No problem. Just tell Google Assistant to do so via your smartphone.

More and more of us are turning to this tech to make life easier. Nearly four years after the Amazon Echo – the first major smart speaker – hit the UK market, YouGov research reveals that one in four Britons (27 per cent) now own a similar device. And, according to Statistica, forecasts suggest that by 2024, there will be 8.4 billion digital voice assistants around the world – that's more than the predicted global population.

Voice recognition dates back to the 1950s. In 1952, Bell Laboratories in the US created the Automatic Digit Recognition machine or 'Audrey'. At almost two metres high, the vast machine could recognise the voice of its developer HK Davis speaking the numbers zero to nine with more than 90 per cent accuracy. A decade later, IBM developed 'Shoebox', which was able to understand and respond to 16 words.

In the 1970s, Carnegie Mellon University's 'Harpy' hit the 1,000 word mark – similar to a three-year-old's vocab, while Bell Laboratories developed a system capable of interpreting a number of voices at the same time. But, a big breakthrough in the 1980s came about when machines were programmed to look for patterns in sounds, estimating the likelihood that an unknown noise might be a word.

Speech recognition took another leap forward in the 1990s as PC processing power ramped up. Then, the launch of the Google Voice Search app for the iPhone opened voice recognition up to millions, and Google was able to collect data from billions of searches, helping to predict what was actually being said. Spotting its success, in 2011, Apple launched its own version – Siri – before other voice recognition apps exploded onto the market.

It wasn't long before the tech giants spotted an opportunity to develop voice recognition tech for use in virtual assistants. Smart speakers were developed to perform simple tasks, like playing a song, turning off a light or reading the weather forecast – and they could now gather vast oceans of data on how we speak, learn from this information and build products that we can interact with naturally as we go about our daily lives.

Smart home

Today, Alexa is thought to have more than 100,000 skills, many involved in automating your home to suit your needs. From ovens and washing machines to vacuum cleaners, any home appliance can hook up to a smart home hub and work together to do the boring stuff for you. For example, when you leave the house, your hub could instruct your thermostat to drop the temperature, turn the lights off and lock the door. While you're out, smart speakers could act as security devices, listening out for signs of trouble like a smoke alarm or an intruder breaking glass. And the dishwasher and vacuum cleaner could be programmed to have their jobs done by the time you get home.

All this interconnectedness comes at a cost, of course. The more chore-busting gadgets hooked up to the hub, the more we need to be mindful about how they can potentially increase our energy usage – and our bills. For example, on average smart speakers cost about £5 a year to run. Often they're left on standby, so it's worth considering whether you need them on 24/7. This is where a smart meter can help.

Smart meters are replacing analogue energy meters across Britain, where homes are responsible for producing 25 per cent of

the nation's CO_2 emissions, with domestic electricity and gas usage equating to about a quarter of those. For no extra cost, your energy supplier can install a smart meter with a display that shows how much energy you're using and what that equates to in pounds and pence. That way, you can keep an eye on how your energy needs evolve, and then make changes to save yourself some cash.

Where once the technology to support voice recognition was pricey, today it is relatively cheap. As it becomes easier to mine speech data, and devices are developed that anticipate users' needs, virtual assistants will become even more advanced with smart gadgets at the heart of the home.

Why get a smart meter?

Some 50 per cent of smart meter owners think their gas and electricity use has reduced since they had a smart meter installed

The average UK household spends an estimated £35 per year leaving electronic devices on standby

If every UK household took action on energy efficiency now, we could save up to 54 million tonnes of carbon dioxide

smart energy GB
Join the energy revolution

Join the **energy revolution** and contact your energy supplier to **request a smart meter.** For more information, visit **smartenergygb.org**

Affordable, award-winning headphones p41

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

Airships, as seen in this graphic, could be a low-emissions way to transport freight

AIRSHIPS READY FOR TAKE-OFF

LOCKHEED MARTIN

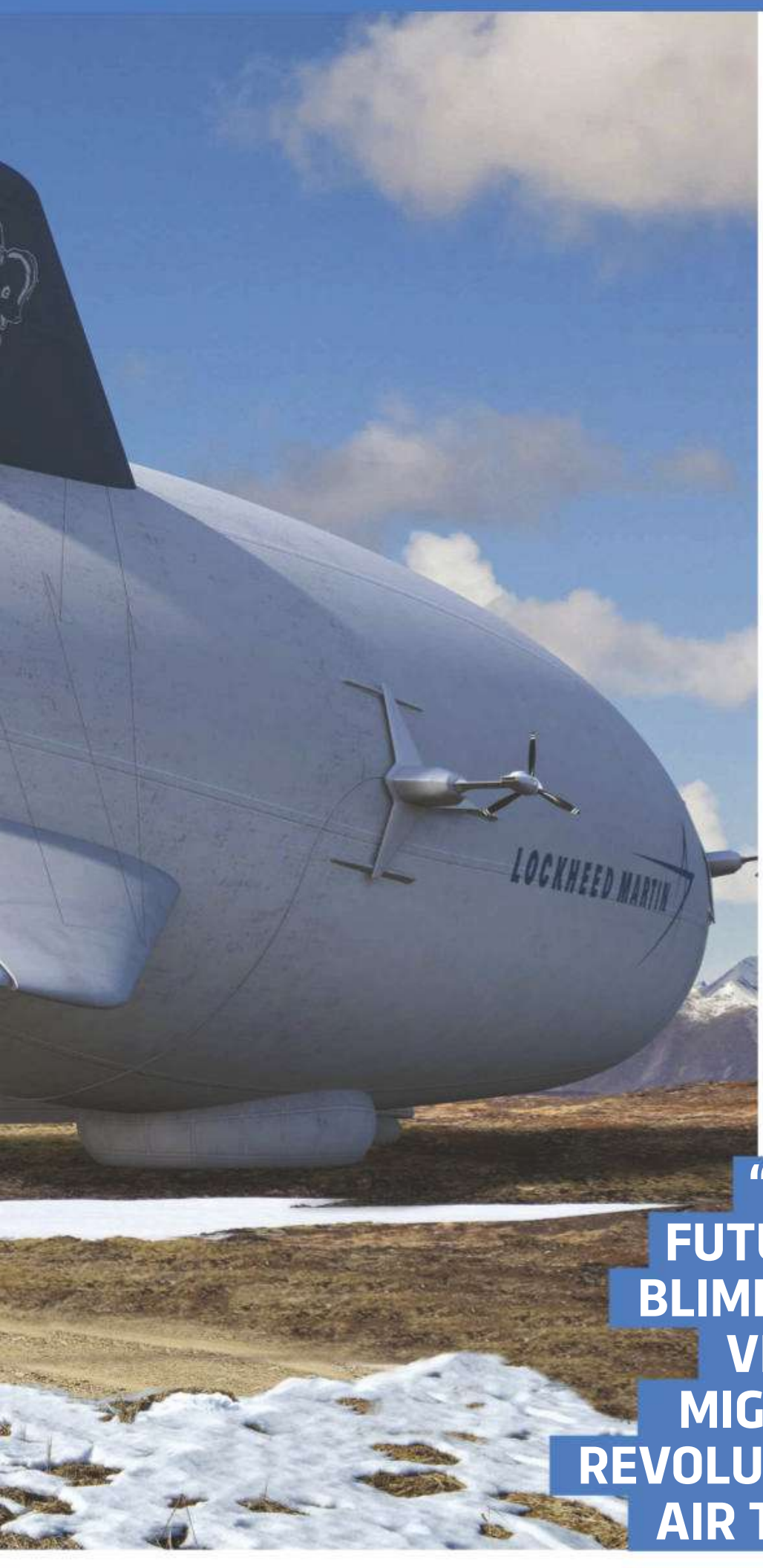
Skunk Works is an arm of the aerospace giant that develops new aircraft. It has created a demonstrator airship that it believes is ready for commercial deployment, delivering aid in disaster zones or minerals from remote mining sites. It's also made a robot that crawls across the exterior of the blimp, repairing tiny holes.

FLYING WHALES

This French manufacturer is developing an airship designed for freight that picks up and drops off its payload without actually landing. Using helium to hover above the ground, it will have winches that lift or lower its payload, saving energy. The vehicle is designed to carry up to 66 tons.

ATLAS LTA

This Israeli start-up is hoping to join a growing airship market with three different designs. Primarily built for transporting freight, cargo bays are built into the airship. Unlike a lot of current designs, the airships would be powered by hydrogen fuel cells, supplemented by diesel.



LOCKHEED MARTIN

"RETRO-FUTURISTIC, BLIMP-STYLE VEHICLES MIGHT JUST REVOLUTIONISE AIR TRAVEL"

TRANSPORT

The new age of the airship

Ian Taylor asks whether a form of transport with a dark past might have a brighter future, as cities rethink their infrastructure

What if you could fly with a fraction of the carbon emissions of a conventional aeroplane? What if you could cruise through the clouds with almost zero noise? And, what if you could board your aircraft without first having to navigate a sprawling airport and all its associated infrastructure?

That's the elevator pitch for a new generation of airships, the retro-futuristic, blimp-style vehicles that might just revolutionise air travel in the coming decade. Dotted around the world, companies from small start-ups to aerospace giant Lockheed Martin are building lighter-than-air, modern-day Zeppelins with a broad range of applications in mind.

One British company, Hybrid Air Vehicles (HAV), recently laid out plans for a series of short-haul flights that would enable city-hopping trips aboard its Airlander 10 craft. Proposed routes include Liverpool to Belfast, Oslo to Stockholm and Barcelona to Palma. And per passenger, HAV claims the carbon footprint of such a flight would be less than a tenth of the same journey in a conventional jet plane, because helium is used as a lifting gas to get the craft airborne.

"Three-quarters of the carbon reduction almost comes for free," says Mike Durham, HAV's chief technical officer. "It's helium keeping us up, so we only need fuel [from four combustion engines] to push us along. Conventional aeroplanes need to burn fuel to stay up as well."

Of course, without a jet engine, airships are considerably slower than modern planes. HAV says its proposed Liverpool-to-Belfast route would take 5 hours and 20 minutes (although a similar journey by ferry would take more than nine hours).

As the world slows down in response to COVID-19 and as we grapple with how to ➤

reduce carbon emissions from air travel and freight, airships may offer viable alternatives – and not just in passenger flights. Hybrid airships are touted for aid drops, search and rescue, eye-in-the-sky command centres and tourism. Imagine a bird's eye tour of the North Pole or Great Barrier Reef. Some believe luxury airships could even become playthings of the super-rich, decadent floating mansions that offer the same status as a luxury yacht.

"WE CANNOT SPEND OUR TIME RUSHING AND TEARING ABOUT THE PLACE, IGNORING THE PLANET. LIGHTER-THAN-AIR TRAVEL CAN SUPPORT THAT DRIVE TO BECOME GREENER"

LOCKHEED MARTIN

HIGH FLYER

The most practical application, however, lies in freight. "I've long believed that hybrid airships would be best placed to disrupt global shipping, given their volumetric capacity, the increasing desire for rapid delivery of goods from overseas, and the fact that their speed and operating cost would enable faster delivery than by ship, with a proportionally lower increase in transportation cost," says John-Paul Clarke, professor of aerospace engineering at the University of Texas at Austin.

International shipping doesn't have to be fast, so transporting food or chemicals by airship could save significant carbon emissions compared to large freight vessels at sea. Yet for all their green credentials, some argue that helium-powered airships are not the future of green transport.

"The main source of helium production is oil and gas extraction," says Julian Hunt, a researcher at the International Institute for Applied Systems Analysis in Austria. "If the main driver for a future airship industry is to reduce aviation CO_2 emissions, a helium-based airship industry will have to rely on a functioning oil and gas industry. It does not make sense."

Hunt has proposed using the jet stream to propel airships at far greater altitudes than something like the Airlander plans to fly.

But if helium isn't the answer, then it raises two alternative H-words, both with rather negative connotations: hydrogen and Hindenburg. In 1937, the most infamous airship that ever flew exploded in mid-air and crashed in front of photographers and filmmakers, killing 36 people. Powered by (flammable) hydrogen, the crash was a PR disaster that contributed to the demise of airships as a popular mode of transport.

That was over 80 years ago. Most in the industry believe hydrogen's comeback is inevitable.

"Hydrogen is the obvious alternative to helium," says Clarke. "It can be produced greenly and more and more cheaply with each passing day. It has an unfortunate reputation due to past accidents [but] we have learned a lot over the years about how to handle hydrogen, especially in transportation settings, and it is now being used to propel cars, trucks and aircraft."

So what's it like to fly in an airship? According to Durham, a trip on HAV's Airlander would be a lot smoother than modern flight.

"It's a low-noise, low-vibration, low-turbulence cabin space, where in many operations you may even be able to open a window. It's also got floor to ceiling windows, so the ambient light is different as well. The cabin has a lot more volume per passenger."

Clarke and Hunt both doubt that airships offer a viable alternative to short-haul flights, citing issues like wind variability and logistical issues, but Durham remains optimistic.

"There will be sweet spots that work for our product and there will be spaces that won't work. It's probably not going to work for long-haul flights," he says. "I think they have a place to play in society moving forward. The human race is going to have to come to terms with the fact that we cannot spend our time rushing and tearing about the place, ignoring the planet. Lighter-than-air travel has a part to play to support that drive to become greener."

Airships could offer jaw-dropping trips without the hassle, noise and discomfort of conventional aeroplanes

Ideas we like...

→

...bioethanol fireplaces

Although it's hard to deny the charm of a log burner, it looks like their days are numbered as the government looks set to ban the most polluting fuels used in them to curb emissions. There is a greener alternative – a biofuel burner. These fireplaces from Danish company Le Feu burn bioethanol, an alcohol produced from biomass like plant waste or straw. This burns cleanly, while providing enough heat to warm a room of 20m^2, the company claims. You don't need a chimney to install one, although Le Feu recommends cracking a door open to maintain airflow. Unlike your old log burner, you can move this eco-burner around and get it to face you or take it outside. We trust our readers are smart enough not to do that while the fire's on!

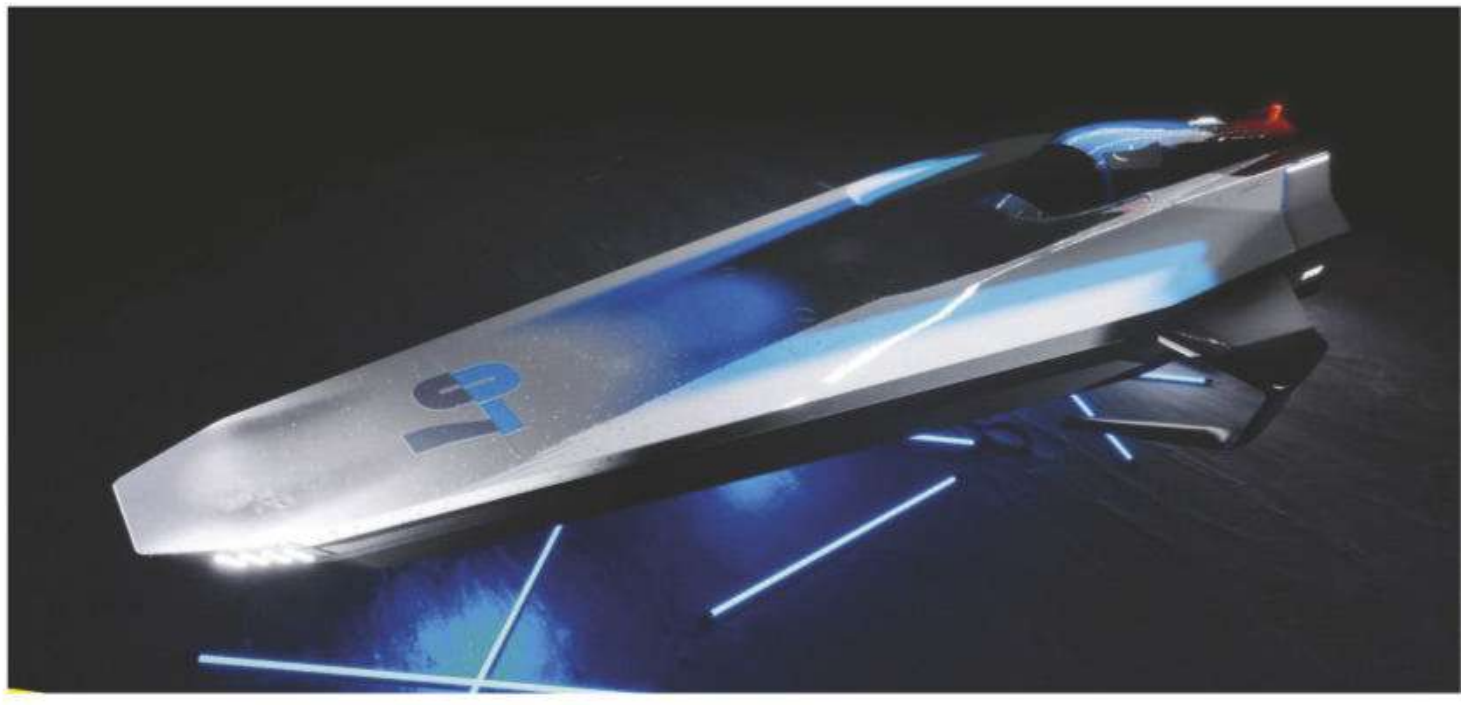
Le Feu bioethanol fireplace
From £1,599, lefeu.co.uk

↑

...a speaker that looks like the Death Star

It's rare to find something totally new in home audio, so this spherical speaker has definitely caught our attention. Syng is founded by a former Apple designer, who says that this is the world's first 'triphonic' speaker, which means it uses three speakers to build sound that fills your room in a more 'accurate' way. This doesn't sound totally barmy, but we'll have to wait to hear one in the flesh before we give our verdict. If you've got the spare cash lying around, the company actually suggests you buy three of the speakers for the optimum setup.

Syng Cell Alpha
$1,799 (£1,274 approx), syngspace.com



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...watersports go electric

Normally we'd advise against mixing water and electricity, but look at that boat! The E1 Series will be the first all-electric powerboat racing championship, founded by some of the minds behind Formula E. This is the boat the racers will use. The E1 RaceBird powerboat will glide above the water's surface, using hydrofoil technology that minimises drag and instead uses the upward force of the water to propel the boat up, out of the water and forward. This, along with its electric motor, will help it to reach speeds up to 50 knots, or 93km/h. After a thorough design process, the RaceBirds are now in production and hope to be race-ready later this year. Once complete, 12 competitors will race at locations around the globe in the UIM E1 World Electric Powerboat Series.

E1 RaceBird, e1series.com

↑

...sci-fi lights

These night lights have built-in motion sensors so that they light up when you walk past. They've got light sensors too, so they'll sense when it's dawn and shut down. They're lightweight, battery-powered and magnetically snap to a frame that attaches to the wall with sticky tape, so they're a doddle to install and ideal for anyone renting a home. Plus, a series of lights can be cleverly linked up so that when you pass the first light, the rest of them illuminate the way.

Wyze Night Light
$19.99 (£17.19 approx), wyze.com

↓

...an (almost) smoke-free fire pit and grill

We love bonfires (and barbecues!) but it does get tiresome having to dance around the fire all evening to dodge the eye-watering smoke. The FirePit+ eliminates smoke by making your fire hotter. Battery-powered fans at the bottom of the fire basket stoke the flames from beneath, while the mesh sides let plenty of air in. The improved airflow means the flame burns hotter and more efficiently, therefore producing less smoke. Plus, you can put some charcoal in and rest a grill on the top. The fans last between 7 and 30 hours depending on how high they're turned up, and the battery can be recharged via USB.

Biolite FirePit+
£269.99, uk.bioliteenergy.com

→

...affordable award-winning headphones

We love the build and design of Grado's headphones. They sound warm, lively and full of bass, while looking both retro and minimal. They've recently updated their award-winning range and our pick of the lot is the SR80x. They're open-backed, which means the audio will bleed out a little, so you may not want to take these on the train, but it does make them lighter and more comfortable to use at home for long periods and it'll make the audio sound roomier than a closed-back pair. The new headphones have upgraded drivers too, improving the bass and mid-range. Certainly one of the best sets we've worn under the £150 mark.

Grado SR80x
£129.95, gradolabs.com

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This summer, BBC Radio 2 is encouraging everyone to help the bees with its Big Bee Challenge. **bit.ly/big-bee-challenge**

Colonies of feral bees, thought to have died out decades ago, are generating a buzz in Germany's ancient beech forests…

Words **DR CLAIRE ASHER**

Images **INGO ARNDT/NATUREPL.COM/ALAMY**

THE SECRET LIVES OF HONEY BEES

Since the Middle Ages, humans have had a close relationship with honeybees as we've captured and reared them for their valuable and delicious honey. Over time, however, captive honeybees started to outcompete wild honeybees, which were also losing habitat as their native forests were cut down. Then in the late 1940s, beekeepers in Africa started to see outbreaks of a virulent parasite – the *Varroa* mite – which quickly spread to hives in Europe and the Americas.

Now virtually every commercial colony in the world is infected with the *Varroa* mite, requiring treatment to prevent complete colony collapse. Because of the widespread distribution of the *Varroa* mite, people assumed that wild honeybee colonies must have also come under attack and been wiped out from their forest habitat in Europe.

So when Benjamin Rutschmann and Patrick Kohl – both PhD researchers at the University of Würzburg, Germany – headed out into the forest in search of wild honeybees, they didn't know if they would actually find anything. They set up artificial feeders to attract honeybees in Hainich forest, northwest Germany, and then tracked the foraging bees back to their nest. Against all expectations, they found some wild colonies were still present in this ancient beech forest. Suddenly, a fun weekend project between friends turned into a concerted scientific effort to map and monitor the bees that so many people thought had long since vanished.

ABOVE A honeybee returns to an experimental beehive as part of a study on optical orientation and memory

“WE CAN FIND A COUPLE OF HONEYBEE COLONIES A DAY, BECAUSE IN THE SUMMER ABOUT 10 PER CENT OF ALL THESE WOODPECKER CAVITIES ARE OCCUPIED BY HONEYBEES”

Rutschmann and Kohl found the wild bees were often nesting in abandoned tree cavities created by black woodpeckers (*Dryocopus martius*), which are one of the few locations in these forests with enough space for the bees to house their food stores for the long winter months. Scientists studying black woodpeckers were able to provide precise coordinates of around 500 abandoned tree cavities in Hainich forest as well as the Swabian Alb Biosphere Reserve in southwest Germany. “Every year we check all of these trees,” says Rutschmann. “We can find a couple of honeybee colonies a day, because [in the summer] about 10 per cent of all these woodpecker cavities are occupied by honeybees.”

Extrapolating from their data, they estimate that Germany’s forests may be home to several thousand wild honeybee colonies. However, these bees are not the stalwart survivors of an ancient dynasty of wild bees – they are more likely to be descendants of escaped swarms from commercial hives that have re-established in the woodland. Rutschmann doubts they are forming long-term self-sustaining wild populations. “It looks very tough for these bees,” he says.

ABOVE Wild honeybees in German forests can often be found nesting in the abandoned tree cavities left by black woodpeckers (*Dryocopus martius*), like this one in Swabian Alb Biosphere Reserve in southwest Germany

BEES IN THE BEECH

Studying wild honeybee colonies in detail is no simple task. The cavities can be anywhere from 8 to 80 metres off the ground, meaning that researchers have to winch themselves into the tree canopy to get a glimpse.

To get a better view, photographer Ingo Arndt created a semi-natural nest by attracting a nearby colony to a fallen beech tree that he ➲

had moved to his back garden. During the six-month project, he took more than 60,000 photographs, capturing behaviours that had only previously been observed within the constraints of commercial honeybee frames.

For example, during the early stages of building the honeycomb, workers can be seen linking legs to form a long chain. "These are often referred to as 'festooning bees'. Lots of ideas have been advanced about why they do this, including acting as scaffolding for the developing comb and as a way of measuring space, but at the moment this is still something of a mystery," explains Adam Hart, entomologist and professor of science communication at the University of Gloucestershire.

The chains are usually a single-bee wide, but Arndt's semi-natural hive has revealed far more complex chain-forming behaviours. "When the bees erect their combs freely in the three-dimensional space of a tree hollow, a sort of 'bag' of living bees, interlocked with one another, forms on the ceiling of the hollow," explains Jürgen Tautz, retired professor in honeybee biology at the University of Würzburg. "The net appears extremely flexible, its 'meshes' pulled tightly together at times and spread wide apart at others."

This net of bees remains in place after the honeybees have constructed their comb, and Tautz speculates that it may protect against intruders and help control the climate inside the tree hollow.

HIVE LIFE

Zooming in even closer, Dr Bernd Grünewald, head of the Bee Research Institute at Goethe University in Frankfurt, has placed video cameras inside the honeycomb itself. By slicing a cross-section through the comb and covering the exposed cells with glass, the researchers were able to observe broods developing inside cells for weeks on end. This technique has revealed unique insights into life inside the colony, from workers remodelling brood cells with recycled wax, nurse bees feeding larvae by mouth, and dedicated 'heater bees' using their own bodies to keep conditions inside the cells just right.

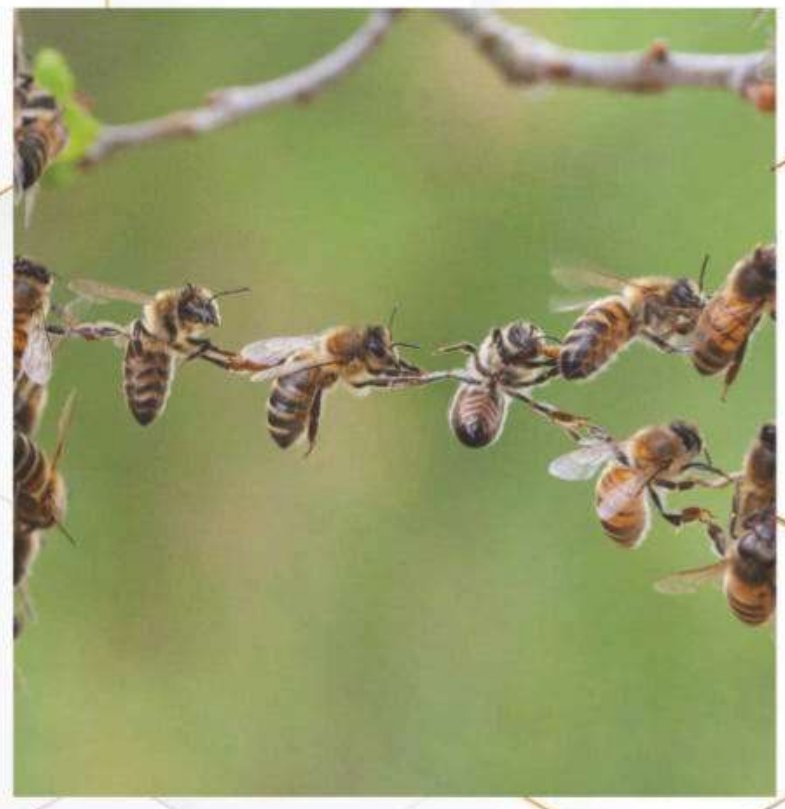
The heater bees' job is to keep the brood cells at a constant 35°C. By climbing head-first into an unoccupied cell and radiating heat, they can warm up to 70 neighbouring brood cells.

"By activating their thoracic flight muscles – the most powerful they possess – bees can generate body temperatures up to 44°C," says Tautz.

Bees use this skill for all sorts of tasks, from warming up the hive to thickening honey. They even use it to defend the nest against attackers, such as hornets. Honeybees have a slightly higher maximum body temperature than hornets and they use this to their advantage by forming a defensive ball around any attackers, essentially cooking them to death. "The bees vibrate their wing muscles, raising the temperature of the ball until the point where the heat kills the hornet. It's brutal, but effective," says Hart. "The crucial thing for the bees is to stop the hornet from getting back to her nest and leading more hornets to the bees." A hornet attack can decimate a honeybee colony in a matter of hours.

As well as attacks from hornets and outbreaks of parasitic mites, honeybee colonies are dealing

"BY ACTIVATING THEIR THORACIC FLIGHT MUSCLES BEES CAN GENERATE BODY TEMPERATURES UP TO 44°C"



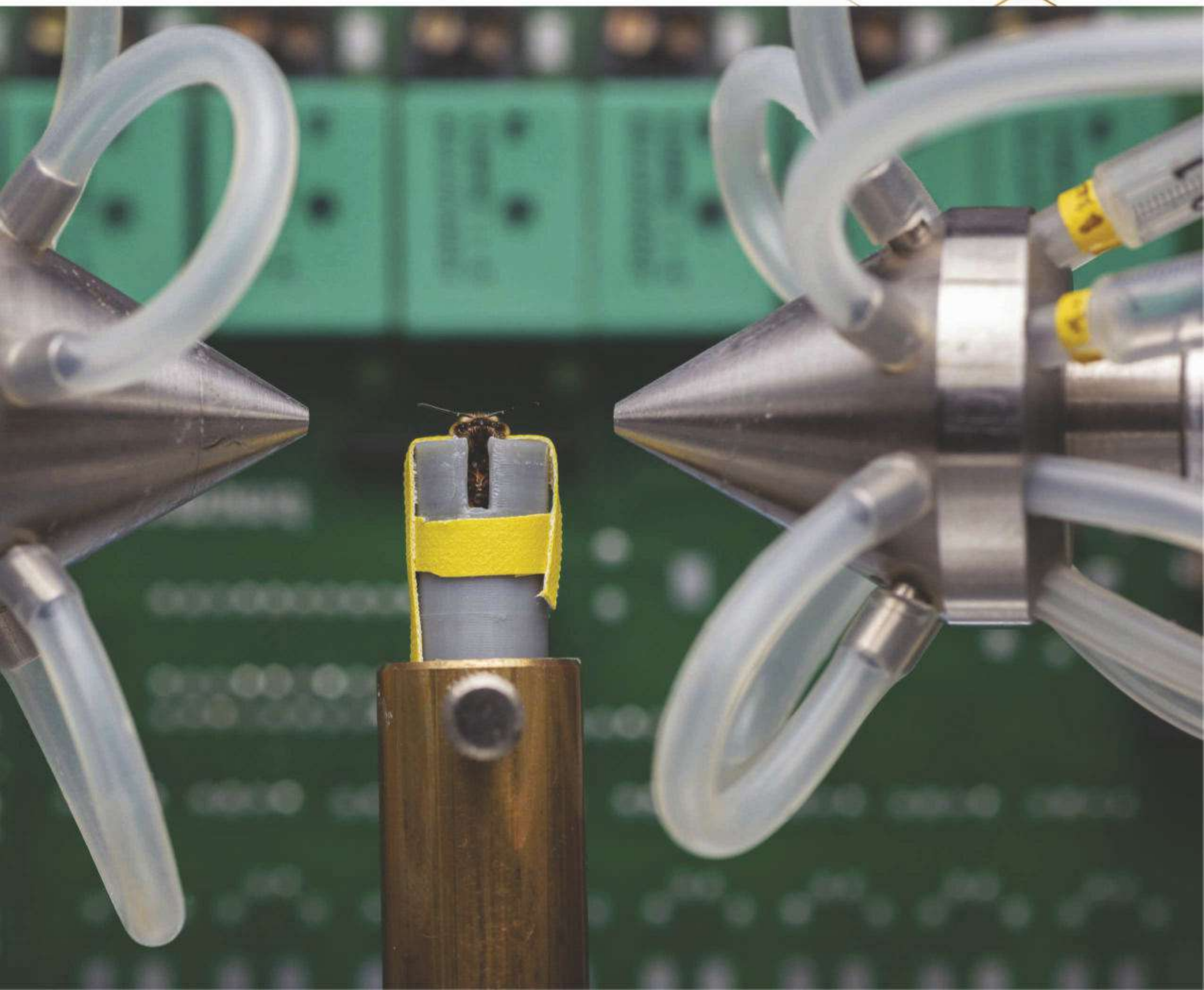
BELOW This unusual experimental setup is called an olfactometer and it allows scientists to blow small concentrations of a particular odour, or in this case an insecticide, over the bee and measure its response

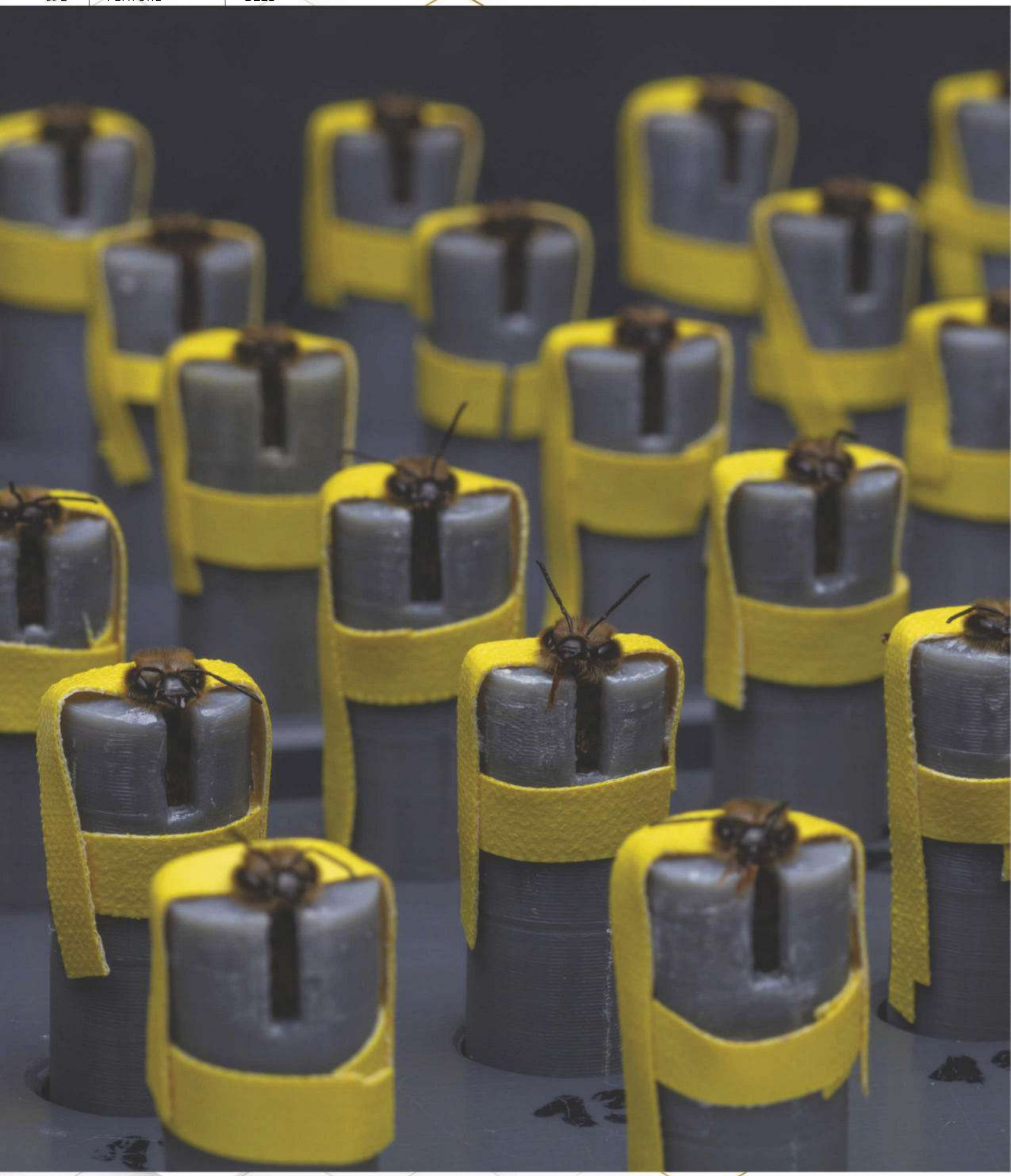
BELOW LEFT In the early stages of building honeycomb, 'festooning' bees link their legs together to form a chain. No one is sure why they do this, but experts suggest it could help the comb to form

with the added stress of insecticide exposure from agriculture. Newly developed chemicals are tested for lethal effects on bees, but the effects of sub-lethal doses can only be detected with careful behavioural experiments. These experimental setups allow researchers to measure how individual bees respond to insecticide exposure by gently blowing low concentrations of the chemical over the bees.

EARN YOUR STRIPES

But captive laboratory hives are not just used to test the effects of pesticides. For decades, bees have been studied to help us further our understanding of their learning and memory, yielding data that may aid honeybee conservation. To study the bees' learning abilities, researchers commonly use harmless restraints to hold them in place while they are exposed to, for example, a particular food or smell. The bees are first chilled down to 4°C (about the temperature of your fridge), which causes them to fall asleep, but doesn't harm them. While the bees are sleeping, researchers can strap them into tiny harnesses. Once in this setup, bees can be taught to extend their tongue-like proboscis in response to a particular stimulus, just like how the dogs in Pavlov's well-known experiments learnt to salivate in response to the sound of a bell. By providing the bees with a sugary treat alongside ➲





LEFT Bees are (harmlessly) restrained in the laboratory as part of a learning experiment

“IT IS ESSENTIAL THEY ARE UNHARMED, BECAUSE IF THEY WEREN’T WE COULDN’T STUDY THEIR MEMORY”

a particular smell, the researchers teach the bees to associate the smell with the food, and after many rounds, the bees will stick out their proboscis in response to the smell alone.

“It does look a little extreme but I have carried out this procedure with honeybees and they are all released safe and well afterwards – indeed, it is essential they are unharmed, because if they weren’t we couldn’t study their memory or how they learn,” explains Hart.

These ‘proboscis extension reflex experiments’ have provided scientists with a wealth of information about the learning and memory capabilities of bees, and the same techniques have even been used to train bees to detect illegal drugs and landmines!

With this arsenal of research methods, scientists are continuing to gain insights into bee behaviour, ecology and conservation, but many mysteries remain. Can wild honeybees survive in the forest long-term, and if not, why not? And what really is the purpose of those bizarre construction nets?

“More questions arose from the studies of the bees in the woods, than we got answers,” says Tautz.

Rutschmann says he plans to continue studying the feral bees in Germany to understand how they find food in the forest environment and what factors affect their long-term survival. Let’s hope they have a bright future ahead. **SF**

by **DR CLAIRE ASHER**

Claire is a science writer with a PhD in genetics, evolution and ecology. She is the co-author of Brave Green World *(£25, MIT Press).*

WHY DOES THE UNIVERSE EXIST?

Stephen Wolfram is trying to find a rule that dictates the Universe. And in doing so, he might even become the first person to finally devise a complete, fundamental theory of physics. Elegant, or what?

WORDS: MARCUS CHOWN

Back in the plague year of 1665-1666, Isaac Newton changed the scientific world, discovering the universal law of gravity and the mathematics of calculus. Now, in the plague year of 2020-2021, is history about to repeat itself? Stephen Wolfram thinks so. The British-born scientist, who lives in the US, claims he has found a route to a fundamental theory of physics that answers some of the biggest questions, such as what is space? What is time? And why does the Universe exist?

"To be fair, a lot of the work was done in 2019 and we were about to start speaking about it in March 2020, but everything locked down for COVID," says Wolfram. "But it is true to say that we have made more progress towards finding a fundamental theory of physics than I dared believe was possible."

Wolfram's starting point was to ask: What is space? "Physicists don't often ask this question," he says. "They merely think of space as the backdrop against which the events of the Universe play out."

According to Wolfram, space is made of a network of 'nodes', which are connected to each other. The nature of the connections – how each node is linked to nearby and faraway nodes – can create a space of any dimension. So if the number of nodes increases as the square of the distance from any given node – like the surface area of a sphere – the network has the properties of familiar 3D space. "I actually believe the Universe started out with infinitely many dimensions and gradually cooled down to the three we have today," says Wolfram. "But I don't yet know why there are precisely three."

Wolfram is interested in what is the minimal 'stuff' needed to create the Universe. And in addition ➤

to the network of nodes – 'the atoms of space' – there is another ingredient, the 'rules' that change the network. So, for instance, a rule will say: 'wherever there is a particular pattern of nodes, replace it with another particular pattern of nodes'.

"It is the application of such rules, over and over again – the continual updating of the space network – that knits together space," says Wolfram. "The miracle is that this process can also create all the matter in the Universe and all laws of physics we have discovered over the past 350 years."

THE UNIVERSE IN A COMPUTER

Before examining this remarkable claim, it is worth considering how Wolfram got to this point. Born in London in 1959, he was publishing physics papers at the age of 15. As a graduate student at the California Institute of Technology in Pasadena, he worked with Richard Feynman, arguably the most notable post-war US physicist. But a crucial event for Wolfram was a discovery he made in 1981 when he used a computer to investigate the consequences of simple computer programs – ones whose output is repeatedly fed back in as their input, like a snake eating its own tail.

The simplest computer programs he could think of at the time were cellular automata. These are one-dimensional lines of squares, each of which can be empty or filled. A rule is applied that replaces a certain pattern of squares with another. In this way, a new line of squares is created. And another new line. And so on.

Most of the time Wolfram found that nothing interesting happened. In some cases, however, there were persistent features that moved across the evolving cellular grid, reminiscent of subatomic particles in the real world. But the big surprise was that there were a few rules that created neverending novelty and complexity. This was a light bulb moment for Wolfram. Usually, simple programs have simple outputs and complex programs have complex outputs. But Wolfram had discovered simple programs with complex outputs. His immediate thought was, "Is this how the Universe creates a rose or a newborn baby or a galaxy? Is it merely applying a simple program over and over again?"

In 2002, Wolfram published *A New Kind Of Science*, a 1,200-page tome with 1,000 black-and-white pictures and half a million words. In it, among other things, he explored the consequences of all 256 possible rules for one-dimensional cellular automata, among which was Rule 30, which generated unlimited complexity. The book was met with hostility from the physics community. Partly, it was because he had published it himself without going through the usual peer review process. But another reason was that other physicists could not see how to use his ideas to predict anything useful.

They had a point. Basically, Wolfram was saying that most of what the Universe is doing is 'computationally irreducible' – that is, the outcome can be discovered only by running the computer program for the 13.82 billion years the Universe has been in existence. To many other physicists that was a fat lot of good.

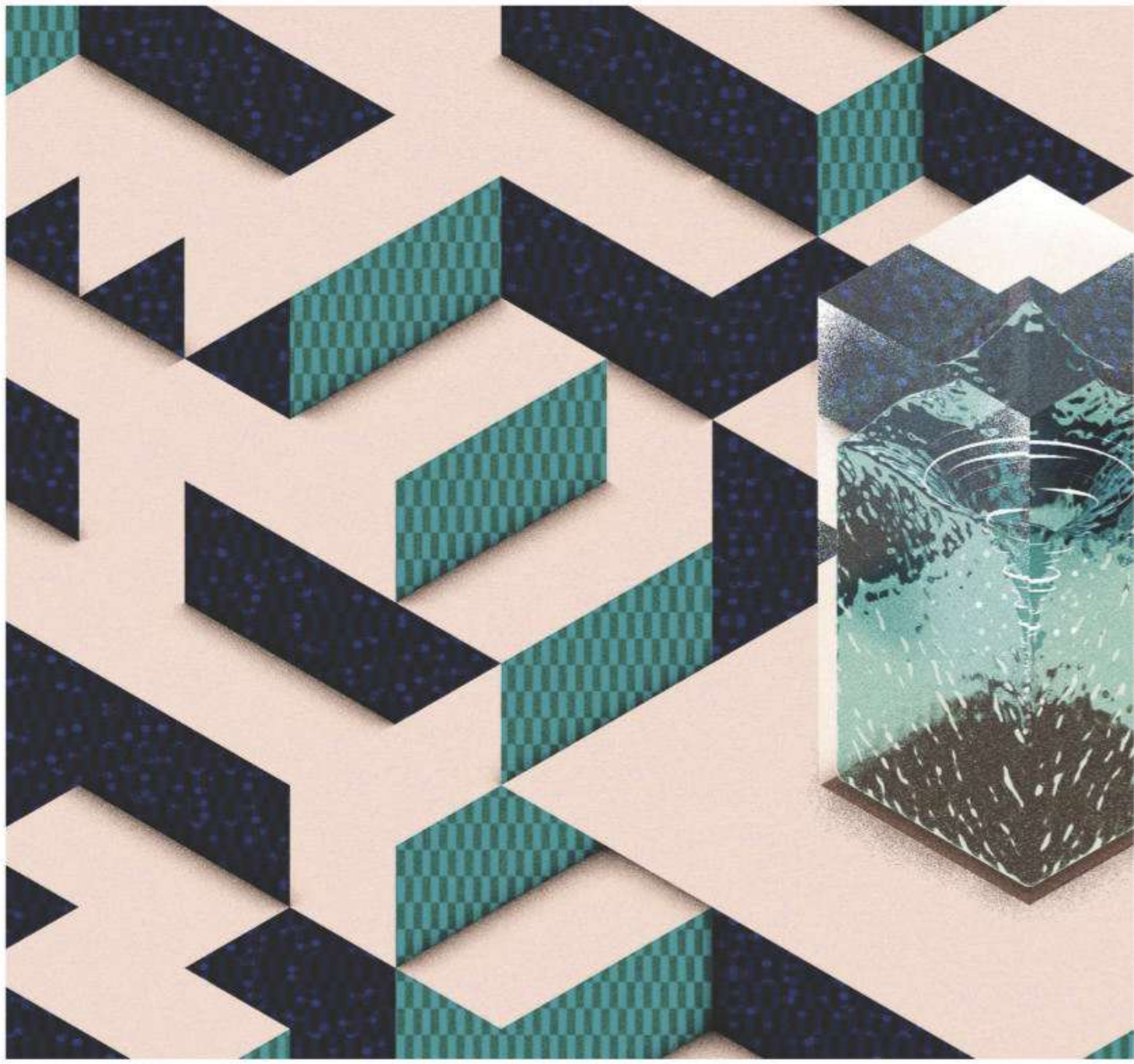
But Wolfram was also saying that, within the Universe-generating computation, there are 'computationally reducible' islands, where it is possible to deduce the outcome without actually running the program. "These shortcuts are none other than the laws of physics we have discovered," says Wolfram.

In the end, Wolfram did not pursue the ideas he had laid out in

"THIS PROCESS CAN CREATE ALL THE MATTER IN THE UNIVERSE AND ALL LAWS OF PHYSICS"

RIGHT Stephen Wolfram may be on the way to unlocking a theory that could answer some of the biggest questions in physics

WOLFRAM RESEARCH INC ILLUSTRATION: TOM STRAW



A New Kind Of Science. On the one hand, he says, there was no demand from physicists. And on the other hand, there was demand for his software such as the computer language Mathematica and the intelligent search engine Wolfram Alpha, which had made him a billionaire. He therefore spent the next two decades developing them instead.

But in 2019, he met some young physicists who encouraged him to continue his search for a fundamental, computational theory of physics. And, at the age of 60, it was now or never.

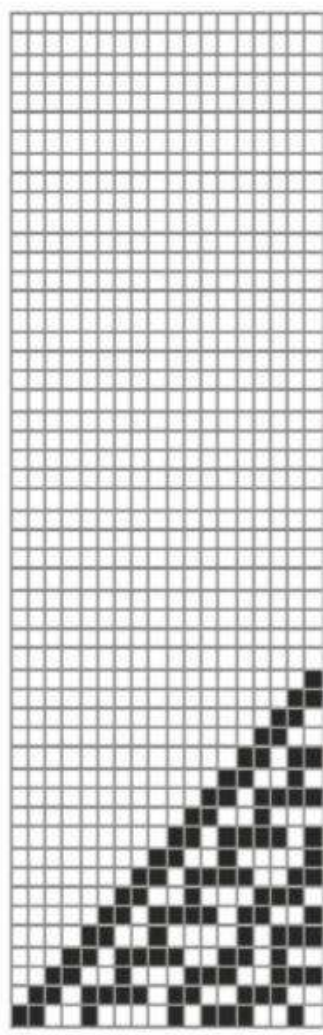
MAKING SENSE OF THE MESS

The problem with cellular automata is that they run on a pre-existing grid. Wolfram realised quickly that he needed something simpler, even more basic. This is how he hit on the idea of a self-updating space network. There are persistent features in the networks, rather like vortices in water, and these are matter. Ultimately, then, everything arises from space. There is nothing else. Actually, that is not entirely true. There is one other thing. "Time, which everyone since Einstein has thought is the same as space, isn't," says Wolfram. "Time is actually the process of step-by-step computation."

One of the problems with Wolfram's earlier approach was that, if he found the program that is generating the Universe – and he believed it might be no longer than four lines of code in his own computer language, Mathematica – the question would then arise, why this program and not another? Wolfram therefore hit on the idea that the Universe is being generated by all possible programs running simultaneously. "At first sight it seems unbelievably messy. How can anything useful come out of this?" he says. "But the miracle is that everything does, including the twin pillars of modern physics: Einstein's theory of gravity [General Relativity] and quantum theory."

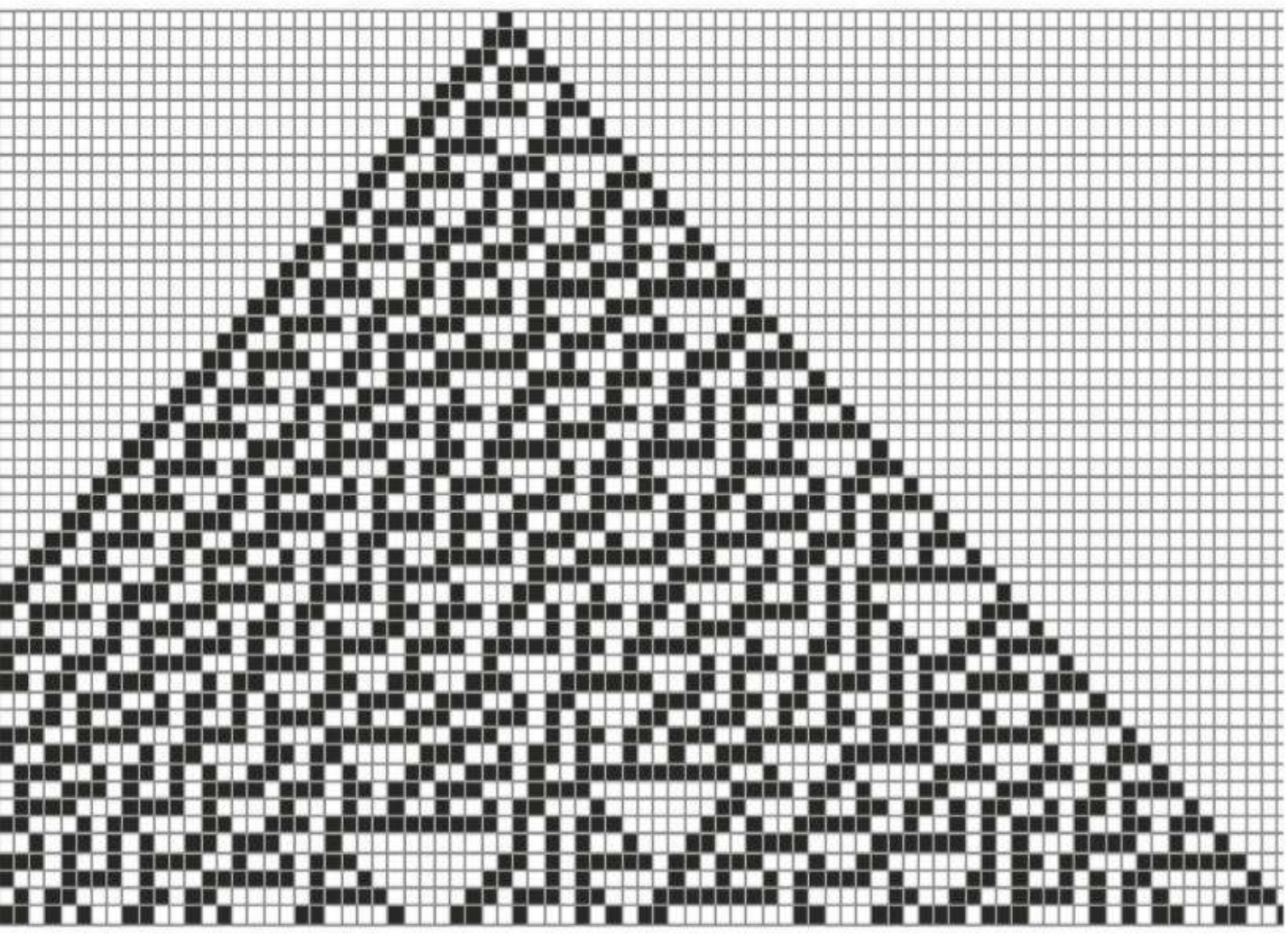
The key thing is to realise that we are not observing the Universe from outside. That is impossible. Instead, we are pieces of self-updating space network within the overall self-updating space network of the Universe. Not only are we limited in the amount of computation we can do and so unable to perceive most of the irreducible computation going on all around us but

"GENERAL RELATIVITY AND QUANTUM THEORY ARE BASICALLY THE SAME THEORY!"



RICHARD LING/WIKIPEDIA ILLUSTRATION: TOM STRAW

BELOW From order there was chaos: Wolfram's Rule 30 found that even a simple rule that determines the colour of cells in a row can generate complexity



we are also limited by our biology, which causes us to impose a single thread of time on what we see. "Despite the fact that all possible rules are actually operating, our sampling will reveal a single rule generating the Universe," says Wolfram.

ROUND THE BEND

Crucially, our fundamental limitations do not permit us to see the atoms of space. Instead, we see them linked together to make a smooth continuum – a continuum, furthermore, that is described by General Relativity. In Einstein's theory, masses like planets follow the shortest path, or 'geodesic', through space-time. Space-time is in turn warped by the presence of energy (strictly speaking, energy-momentum). According to Wolfram, energy in his picture is nothing more than the amount of activity going on at any location in the network, and it is this computation that ultimately bends the geodesics of massive bodies.

Quantum theory, in contrast, describes the microscopic realm of atoms and their constituents, and is notorious for appearing fundamentally incompatible with General Relativity. Specifically, there is no such thing as a unique path through space. Atoms can follow multiple paths, each with an associated probability. According to Wolfram, this multiple history is built into his framework because, each time a piece of space network is updated, it can be updated by not just one rule but multiple possible rules, leading to multiple histories. "Quantum theory is not a bolt-on, as in standard physics," he says.

Wolfram goes further. He imagines a 'branchial space' that encapsulates all these multiple histories. And this requires the tools of Mathematica to visualise, which is one reason why other physicists, not just mere mortals, find it hard to follow Wolfram. However, the key thing Wolfram claims is that General Relativity, with its geodesics bent by energy-momentum in normal space, is exactly the same as quantum theory with its geodesics bent by energy-momentum in branchial space. "General Relativity and quantum theory are basically the same theory!" he says. "I never expected to discover such a lovely result."

This is indeed an astonishing result. In mainstream physics, only string theory provides a framework that unites General ➤

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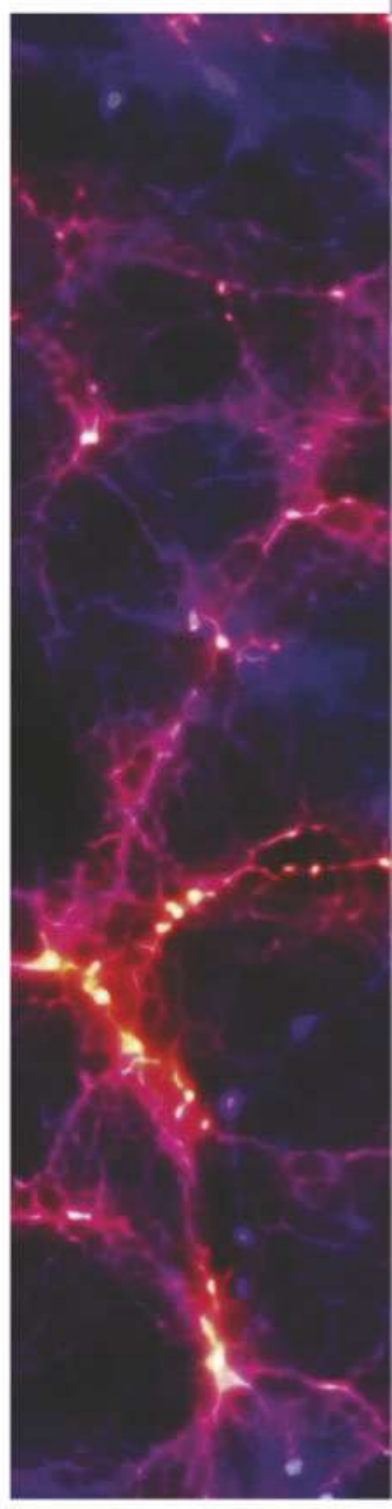
Relativity and quantum theory, and it has big problems, not least the fact that it leads not to a single universe but to a multiverse of about 10,500 universes. There is a strong hint, however, known as the 'holographic principle', that quantum theory and General Relativity are intimately connected and that quantum theory manifests itself as General Relativity in a higher dimensional space. Wolfram sees his work as confirming this connection.

Carlo Rovelli at Aix-Marseilles University works on 'loop quantum gravity', a rival of string theory, which attempts to show that space-time, down at the impossibly small Planck scale, is made of finite loops woven together into a complex shifting network. Is there any connection between Wolfram's work and loop quantum gravity? "Indeed, I have been curious about the same question!" says Rovelli.

Others find Wolfram's work fascinating. One is Gregory Chaitin, the Argentinian-American who invented a field of mathematics – algorithmic information theory – when he was 15. "I personally think his new work is very interesting," he says. "And, yes, something like General Relativity and like quantum mechanics emerges rather naturally." Chaitin likes the originality of Wolfram's approach. "What is fun is that this is completely orthogonal [distinct] to what everyone else is doing. Up to now, string theory has been the only game in town that attempts to operate at this level. Now there is another game."

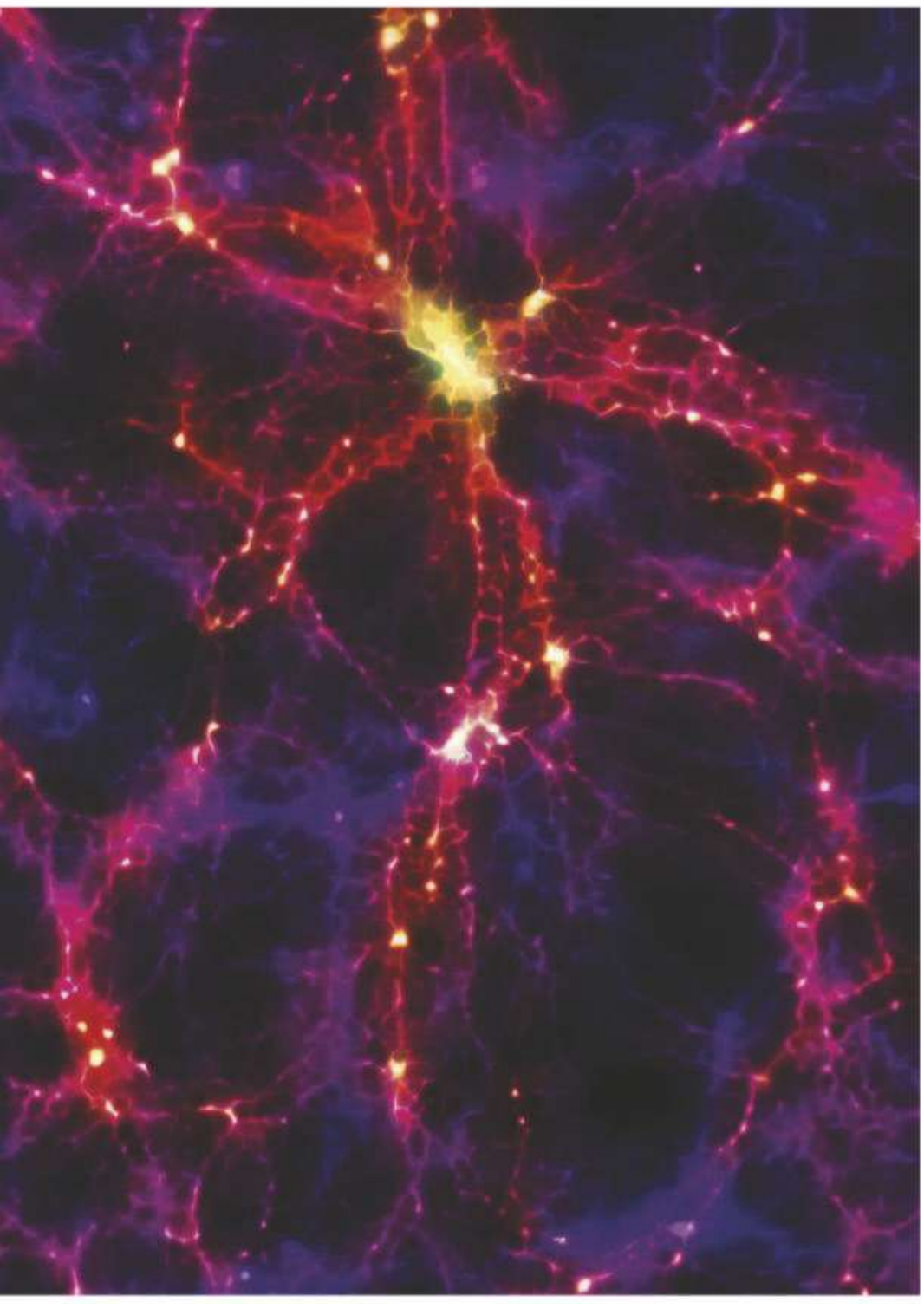


NO CONTRADICTIONS

Wolfram is encouraged by the response to his latest work, which is very different to the response he experienced in 2002. He says lots of the young physicists are attending his seminars, and older physicists are sending their students. He is live-streaming a lot of the development on the web so people can see what he is doing. "I have been surprised at how few people have said this can't possibly work," says Wolfram. "It's been more like 'I can't understand this' or 'tell us what phenomena we can look for'."

Wolfram is also not alone, as he was in 2002. He now has a handful of other physicists working with him. Chaitin thinks this is significant. "Unusually for Stephen, he even gives co-author credit to some," he says. But one of the major differences between now and 2002 is the idea that information-processing is at the heart of the Universe is far more mainstream than it was two decades ago. In a way, nothing Wolfram is doing

"THE UNIVERSE IS THE LOGICAL CONSEQUENCE OF APPLYING ALL POSSIBLE RULES TO DISEMBODIED NODES"



BELOW Artist's impression of the Universe, with galaxy clusters concentrated at 'nodes'

is contradicting accepted physics. He is merely attempting to go beneath the bonnet of the car to reveal the computation that both generates the Universe and the laws of physics that we observe.

One consequence of Wolfram's picture is that aliens with different biologies and different senses may see different parts of the Universe-generating computation and therefore deduce different laws from quantum theory and General Relativity. In fact, they may forever be invisible to us, existing in parts of the space network our senses are simply not sampling. "Our view is limited by our size of about a metre in height and our insistence on seeing a single thread of time," says Wolfram. "But creatures the size of the planet and without this insistence would see something entirely different."

In the end, it will be predictions of new phenomena that will confirm or refute Wolfram's computational universe. And at the moment these are lacking. However, Wolfram sees places that may be fruitful in yielding observational predictions. For instance, he believes there could be domains of our Universe with different numbers of dimensions. And, in particular, he suspects the black holes may be able to spin faster than permitted by standard physics and, in doing so, whole chunks of space-time may break off, something which is impossible in General Relativity.

AN INEVITABLE RESULT

The big question remains, why is there a Universe? And here Wolfram thinks the Universe may exist in the much the same sense that mathematics exists. Mathematics consists of a set of givens, or 'axioms', and the consequences, or 'theorems', that can be deduced from them by applying the rules of logic. Similarly, the Universe is merely the logical consequence of applying all possible rules to a network of disembodied nodes. "It is inevitable that it exists, in the same way it is inevitable that 1+1=2," he says.

We, of course, experience the Universe as a solid thing, not an abstract thing like the edifice of mathematics. However, since we are also made of the same stuff as the Universe – like virtual creatures in a virtual reality – everything appears solidly real to us. Whether or not Wolfram turns out to be the new Newton, the plague year has definitely played to Wolfram's strengths. "I have always worked remotely from my company," he says. "This last year has suited me." He admits there is still a long way to go in getting a fundamental theory of physics. "But I am amazed how far things have progressed in a short time," he says. "I never imagined it would work this well." **SF**

by **MARCUS CHOWN**
(@marcuschown)
Marcus is the author of The Magicians *(£14.99, Faber & Faber).*

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COMMENT

MASKING THE ISSUE

Even when the pandemic is over, you shouldn't shove your face coverings to the back of the drawer

A couple of years ago, if you had seen people in the streets or the shops wearing a mask, you might have thought they were a bit eccentric. Nowadays, the opposite is true. We have become entirely used to this. But will we go on wearing masks when the immediate threat of the coronavirus has receded? I suspect not. Unless COVID-19 rears its ugly head again, I can't see those masks going anywhere other than the back of a drawer. This is a shame, because I suspect we will see a lot more flu around in six months' time (last winter saw remarkably few cases) and wearing a mask could make a difference.

Wearing a mask has, unfortunately, become almost an ideological statement, and certainly a cultural one. One of the clear differences between countries that controlled the initial spread of the virus, like China, South Korea and Taiwan, and countries that didn't was the fact that in the former people were actively encouraged to wear masks outdoors and were happy to do so.

To reduce the spread of COVID-19 or other respiratory viruses, the masks don't even have to be that sophisticated. Last year Prof Trish Greenhalgh, of the Nuffield Department of Primary Care, and research scientist Jeremy Howard, carried out a comprehensive review on face masks which was published in the *British Medical Journal* and concluded that "masks are simple, cheap and potentially effective".

The reason why wearing simple masks has such a big impact on transmission of the virus is not just because they protect the wearer (although there is mounting evidence they do, particularly if someone coughs directly in your face), but also because they can dramatically reduce the amount of droplets an infected person sprays around.

The superpower that respiratory viruses possess is their ability to infect your nose and throat and then jump to other people whenever you sneeze or cough. What wearing a mask does is dramatically reduce the risk of that happening. In fact, as Greenhalgh and Howard say, "If you have COVID-19 and cough on someone from eight inches away, wearing a cotton mask will reduce the amount of virus you transmit to that person by 36 times."

"Even homemade cloth masks blocked out 62.6 per cent to 87.1 per cent of fine particles"

There is increasing evidence they will also protect you. For a study that was published as a pre-print in January this year, researchers from the department of engineering at Cambridge University exposed people to controlled amounts of harmless droplets while they were wearing different sorts of masks. Impressively even homemade cloth masks blocked out between 62.6 per cent and 87.1 per cent of fine particles. In fact, they were far more effective than most people who were surveyed as part of the study believed. As the researchers pointed out, even if that means some viral particles get through, it means you are less likely to get a serious infection.

So keep those masks. Come next winter, when we get the annual flu outbreak, you might feel the need to use them again. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

BBC WORLD SERVICE

Listen to the documentary about Lex Gillette and Wesley Williams on 20 July on BBC World Service. Check *Radio Times* for details.

COMMENT

BEYOND THE MEDAL

A Paralympian and their guide form a partnership based on more than winning

On an overcast day in May I make a right turn on Olympic Parkway in Chula Vista, California. The mountains on my left create a natural boundary between the United States and Mexico; the division that the politicians talk about is rendered meaningless by the land that continues irresolutely over these hills. I turn right onto Gold Medal Way and see my destination.

Today's journey to the Elite Athletic Training Center began in London, during the 2012 Paralympic Games. That event was remarkable for many reasons, including the greatest surge of interest by the general public in this decades-old competition, traditionally dwarfed by its able-bodied kin. It was a game-changer in representation on national television and a social shift in attitudes towards disabled people on the streets of Britain. I was riveted.

I am legally blind, completely dependent on my glasses to see clearly, but I can still see blobs of colour and would know to jump over a barrel if it was in my way. Down on the track of that stadium, and here before me now, are people who can see nothing but darkness, and who sprint faster and jump further than I can dream, with their guides tethered to their sides.

One guide in particular brings me to the Elite Athletic Training Center today, in order to work on a documentary. The guide's name is Wesley Williams, and he's agreed to talk to me. Wesley had his own remarkable track and field career, which stopped short of Team USA. Ageing out as an able-bodied athlete comes early, and that could have been the end of his life in athletics. But then a friend came back from being a guide runner in the Paralympics in Athens in 2004 with stories of glory. Williams signed up to be a guide and spent his first season supporting countless visually impaired athletes over the finish line, over the bar, and into the sand pit. Wesley says he's never been so fit in his life.

"After hours, they make music together, they laugh at the same jokes. It's more than a working relationship"

For the past 14 years, he has been long jumper Lex Gillette's eyes, guiding him to multiple medals and a couple of world championship titles. On competition day, Wesley's job is to locate himself at the end of the runway and do what he can – scream, clap, holler – so Lex can triangulate his position on the track. Then, Lex aims at pace in the direction – the world record is 6.7 metres (22 feet).

In 2012, Wesley collected his first Paralympic medal. It wasn't the first time he'd led Lex to the podium, but London was the first Games that rewarded the work of the guide as well as the athlete. Wesley is at the track with Lex five days per week, from 10am to 3pm, training, lifting, sprinting. After hours, they make music together, they laugh at the same jokes. It's more than a working relationship. They both talk a lot about trust. And this year, with gold medal dreams vacillating along with pandemic responses, the pair stay focused on their goal: to be able to reflect, in 30 years' time sitting on a porch somewhere in the California sunshine, that what they did now meant more than any medal achievement. They made a blind man see, and leap farther than anyone ever imagined. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

BBC RADIO 4 92–95 FM & 198 LW

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

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Prof. Anne-Marie Minihane, University of East Anglia

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WE'RE GOING BACK

Typical. You wait for one Venus mission and then three show up at once. Planetary scientist **Prof Paul Byrne** reveals to **Daniel Bennett** how these missions could help answer one of the biggest questions in science: is Earth unique?

NASA/JPL-CALTECH

PROF PAUL BYRNE

Paul is an associate professor of planetary science at North Carolina State University. His work involves using remotely sensed data, modelling, and lab and field work to understand how planets form and evolve. He's also Venus's biggest cheerleader on Twitter right now, where you can find him tweeting about everything to do with space exploration @ThePlanetaryGuy.

NASA'S DAVINCI+ AND VERITAS MISSIONS, AND ESA'S ENVISION MISSION, WERE RECENTLY CONFIRMED. WE'RE OFFICIALLY GOING BACK TO VENUS. WHY'S THAT SO EXCITING?

There's two reasons. The first is that we haven't done it in a while. When I say we, I mean the United States. The Japanese space agency has the Akatsuki orbiter, which is a climate atmosphere focused orbiter that's been studying Venus for the last five years. And there have been probes sent by ESA that have studied Venus from orbit.

Venus used to be the poster child for planetary exploration. We were interested in it because it was a big, rocky world right next door. It's closer to Earth than Mars. It takes less time to get there. And the optimal alignment for launches happen more frequently than they do for Mars.

And remember Venus isn't like Earth or Mars. You can't see the surface of Venus from space, because its thick atmosphere obscures it from visible wavelengths. This means we've got some fundamental questions for Venus, ones that we've been asking for decades and ones that we've only just discovered. We're now poised to put that right.

AND THE OTHER REASON?

In the last 10 years there's been a growing focus on exoplanets – planets orbiting stars other than our own. Right now our capability to detect them is biased towards planets like Earth and Venus: rocky worlds that orbit close to their star. They're easier to see since they pass their star more often. Plus, we're interested in understanding: are there other Earths out there? Are we unique?

Our ability to resolve the radius of a planet cannot distinguish between a planet like Venus and one like Earth right now. When you see a news story about an 'Earth-like world' you might as well say 'Venus-like world'. We can't tell the difference. It raises a fundamental question. If we find Earth-sized worlds, can we make any reasonable guesses as to what its conditions are? Will we find oceans, trees and clouds, or will we end up at a self-cleaning oven like Venus?

WHY HAVEN'T WE GONE BACK OR GONE IN FOR A CLOSER LOOK?

I genuinely do not know why NASA in particular has not gone back. I have Thoughts, with a capital T. The fact that operating at the surface is extremely technically challenging is definitely part of it. It's easier to do science on Mars and the Moon. You can land and operate on those for quite a while, but you can't on Venus.

But you can stay in Venus orbit no problem for as long as you like. And the only other place in the Solar System that we know of right now that's Earth-like in terms of temperature and pressure is about 55km up in the Venus atmosphere. As bad as it is on the ground, at that altitude it's about one bar, and 0°C. You can put parka on.

In fact, the French flew two balloons above Venus at around that altitude with the Soviet Vega missions in 1985. They operated for about two days in the Venus atmosphere.

So I think there's more to it than just the difficulty. The timing of it is interesting. In 1996, ALH84001 hits the scene. This was a meteorite picked up in Antarctica in 1984, later recognised to have come from Mars, and it was potentially thought to have contained fossilised microbes from the Red Planet.

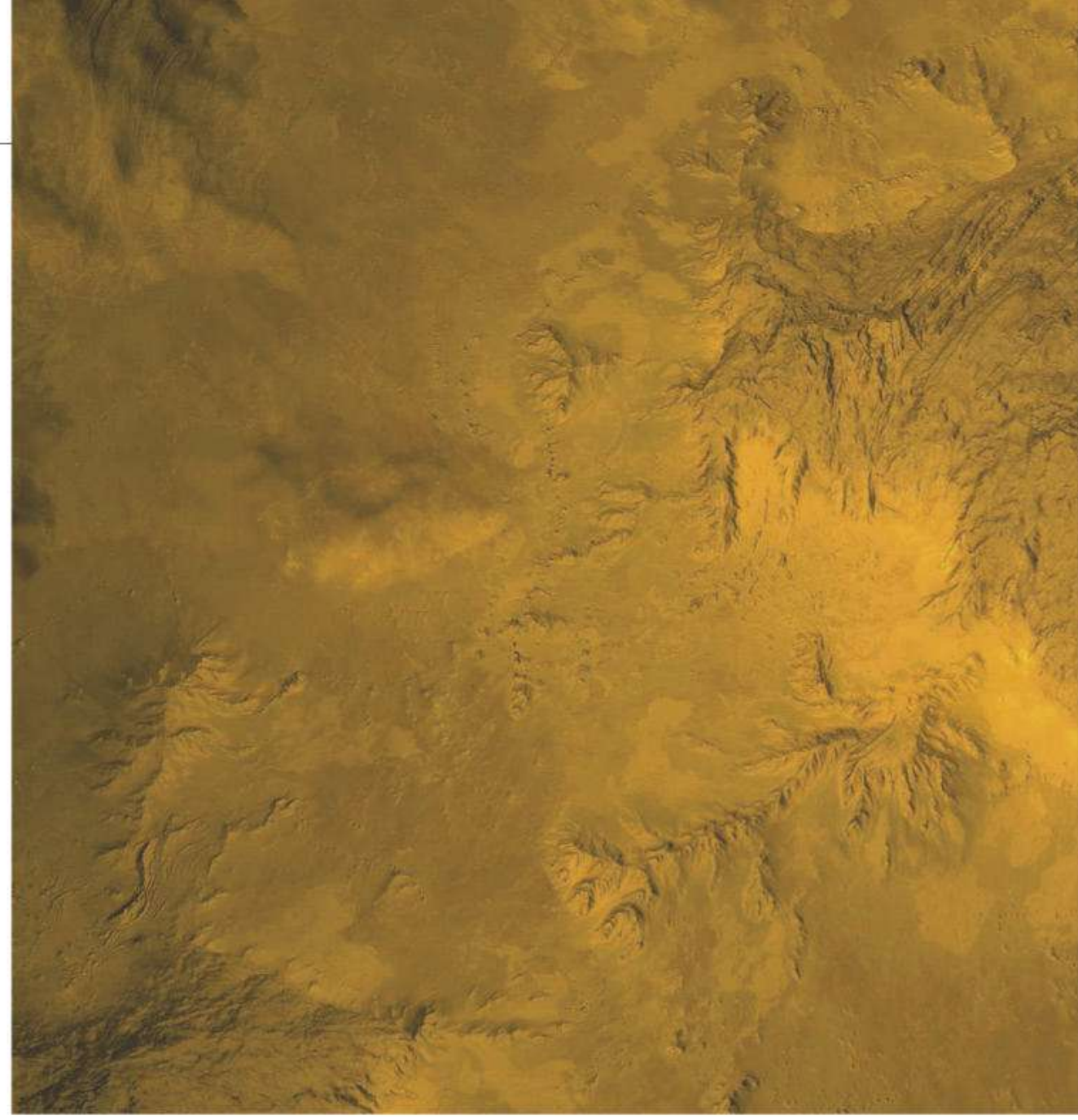
In the end, the overwhelming scientific consensus was that these weren't signs of alien life, but that moment immediately shifted the focus to Mars as a world that was potentially habitable and potentially inhabited. This happened at around the same time that Magellan, the mission that went to Venus, came to an end, and it certainly didn't help the Venus community retain currency. But there is no specific reason why Venus is less scientifically meritorious than Mars, and I think a lot of scientists would agree that Venus is actually more interesting.

BASED ON WHAT WE KNOW, WHAT DO WE THINK THE SURFACE OF VENUS IS LIKE?

It's about 470°C. And it's that temperature everywhere, from the poles to the equator. It's all rubbish. You're not going be set on fire, but you will bake. Venus is in a runaway greenhouse state. And if that doesn't cook you, the atmosphere is 96.5 per cent CO_2. So you'll asphyxiate pretty fast. And then there's the pressure. The atmospheric pressure at the surface is 90 bars. It's the equivalent of being one kilometre underwater on Earth.

Then there's sulphuric acid rain. There's a global cloud layer and those clouds are predominantly made of sulphuric acid. We don't think it rains on the surface. It's too hot. So we think there is some kind of precipitation from the bottom of the cloud layer down, but the rain never reaches the ground. You only have to deal with sulphuric acid when you travel through the clouds. Other than those things it's fine.

If you want to land something, the main problem is the electronics. The landers we've sent in the past will still ➲



be sitting there today. They might be weathered but they were titanium spheres, there's no way they've melted. But the electronics will have fried.

WHAT FUNDAMENTAL QUESTIONS ABOUT VENUS WILL THESE MISSIONS HELP US ANSWER?

Why is it that a planet so similar in size, make-up, age and orbit to the Earth is so unlike Earth? You can almost frame everything under that umbrella. These missions won't solve that, but it will help us address it.

We have two models for how Venus came to be. The first is that the planet was always terrible. It started off in what we call the 'magma ocean phase', which we think most rocky planets do.

The idea is that this early Venus was too close to the Sun to ever cool down long enough to condense the gases in the atmosphere. In particular, H_2O didn't cool enough to form oceans that cover the ground and form crusts, and so it ends up just holding onto a CO_2 atmosphere. This means Venus enters a runaway greenhouse effect [it can't lose as much heat as it's gaining], and so the planet is ruined from the beginning. In which case the answer to why Venus is so weird is that it's simply a function of how far away it is from the Sun. That's it.

The second scenario is that Venus might actually have been just like Earth, with oceans and plate tectonics. One of the most interesting discoveries of Venus missions in the 70s and 80s was to do with something called the deuterium-hydrogen ratio [deuterium is an isotope, or type, of hydrogen]. On Venus we discovered that the ratio is about 100 times higher than that of Earth, and the best explanation is that at some point Venus might have had lots of water and now it's gone. The surface is bone dry. Which means some event triggered this runaway greenhouse effect.

HOW WILL THESE PROBES PROVIDE ANSWERS?

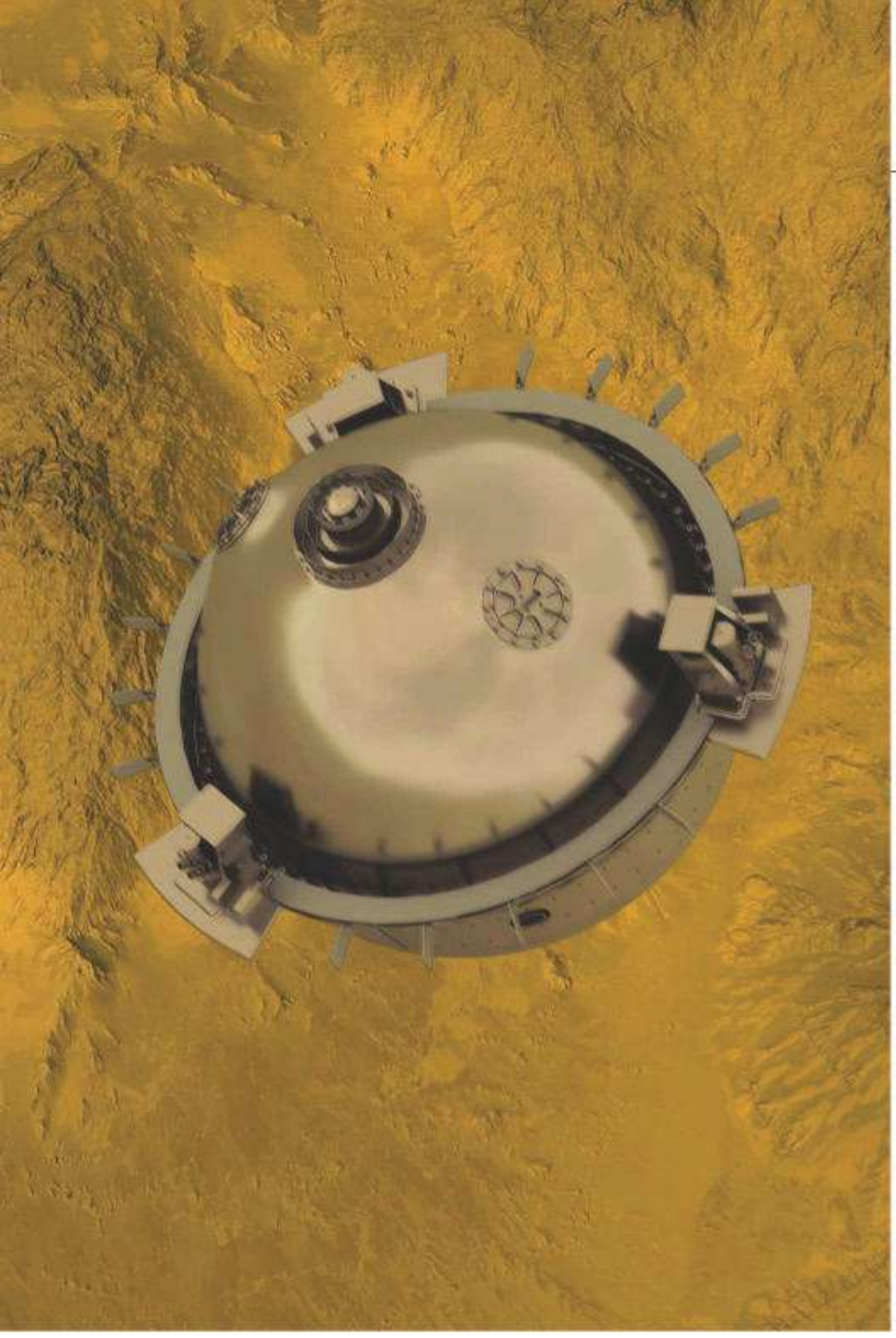
The DAVINCI+ mission will have an orbiter, but the star of the show is the probe which will descend to the planet over the course of an hour on a parachute. Then it will freefall from about 60km towards the surface. It's going to measure the deuterium-hydrogen ratio. Right now the error bar is pretty big on the measurements from the 70s and 80s. That ratio will tell us how much water there was on Venus, but it won't tell us what state it was in.

The water could have been a hot steam filling the atmosphere, or it could have been a cool liquid forming oceans on a balmy surface. To find that out we have to measure the noble gases present. The noble gases are our friends here: helium, argon, xenon, neon. They're tied to different parts of the interior of the planet, and if we look at their concentration, we can build a model of what's been ejected from the planet's interior and get a picture of the history of Venus, and ultimately what state its water might have been in, if it had it.

SO IF WE WORK OUT WHICH OF THE TWO SCENARIOS IS TRUE FOR VENUS, WE'LL HAVE A BETTER IDEA OF JUST HOW UNIQUE EARTH MIGHT BE?

"Whatever we find on Venus is going to be important to make sense of our own planet's history and future, but also what we'll see around other stars too"

ABOVE As the DAVINCI+ probe plunges towards the surface of Venus, it will take a series of high-resolution images



NASA GSFC

This is where it gets interesting. If we find out that it's the first scenario, that Venus was always too hot, that makes things a bit easier. We can just look at a planet's distance from its star and say: "Okay, it's in the Venus zone, it's probably going to be ruined." And then we can test that.

But if it's scenario two, that has big implications. Recent work led by Michael Way, who's at the NASA Goddard Institute of Space Science, has built models to show that cloud layers could have kept Venus cool early on. After that point, the planet should have remained stable. Clearly, something went wrong. And that is where the model suggests that something introduced a whole pile of CO_2 into the air quickly, geologically speaking. The only process that we can think of that can do that is volcanoes. A lot of them. They put a lot of CO_2 into the air. Not as much as humans, but if you have enough big eruptions over a geologically short period of time, it's possible that you could dump enough CO_2 into the atmosphere that you could trigger a climate change.

The whole point of this is to say that we don't know what drives these events, we don't know if they happen on a cycle or if they're kind of random.

If scenario two is correct for Venus, then it begs the question: was it unlucky to have a few volcanoes go off at the same time and go down this irrevocable path of climate change? Or is Earth lucky that this hasn't happened here yet? Maybe Venus is the 'normal' one and maybe Earth is unusual. Whatever we find on Venus is going to be important to make sense of our own planet's history and future, but also what we'll see around other stars too.

WILL WE GET A NEW SENSE WHAT IT'S LIKE TO STAND ON VENUS?

The place they've picked to drop the DAVINCI+ probe is an area called Alpha Regio. It's an area of land on Venus called a tessera. That's not a geological term, it's just what the Russians called it when they discovered this terrain. About 7 per cent of the surface of Venus seems to be covered in tesserae, which is a lot when you consider Venus has no oceans. It [the tesserae] seems to be tectonically formed: there are lots of fractures cut through at different orientations as well as folds. But we don't know what it is. It's unlike anything else in the Solar System.

As DAVINCI+ drops to the surface and the haze clears, it will take a series of images downwards at set altitudes. These will be the highest resolution images we've ever had, they'll let us zoom in and out to understand the structure. Meanwhile, Veritas will provide us with incredibly high-resolution radar data – up to 10 metres per pixel in some places. It'll be like comparing a computer game from the 80s with one from today. We'll see things we didn't even imagine were there. Veritas will give us a much better handle on the structure of Venus, the surface, the interior and even the core.

SO WHAT DOES THE NEXT DECADE LOOK LIKE FOR A PLANETARY SCIENTIST LIKE YOURSELF?

These missions are representing the promise of a second golden age of Venus exploration.

I'm committed to playing my part to make sure that these are not the only two missions that NASA decides to send to Venus in the next 30 years. These two missions will not answer all the questions. However, when DAVINCI+ reaches its final destination, the tessera, it could effectively be looking at a future landing site. It just so happens that there's new research showing that it's possible to build circuit connections, transistors and cables out of silicon carbide, which can function happily at Venus temperatures. So we could see a station that could sit on the surface for 60 to 120 days, that would actually able to test a sample taken from the surface of Venus. SF

ALEXA, WHERE'S MY ROBOT BUTLER?

A machine that does the jobs we don't want – that's what was promised to us by the science-fiction of the last century. Unfortunately, good high-tech help is hard to find – but that's about to change. Jennifer Pattison Tuohy reveals how our homes are about to start looking after us, and not the other way around

by **JENNIFER PATTISON TUOHY**

Jennifer is a freelance journalist with an unhealthy obsession for chips (the techie kind). She writes about the collision of our homes with connected devices for several outlets, including The New York Times.

ALAMY

Most new gadgets get the 'smart' moniker slapped on the side of the box, but are we getting any closer to a truly smart home?

"People don't want a smarter home, they want a better home," says Jamie Siminoff, founder of one of the smart home's most recognisable brands, the Ring video doorbell. Siminoff invented the gadget to see who was at his front door when he was working in his garage.

To date, the smart home has been most successful when it presents a simple solution to a tricky problem and when it makes something just, well, better.

A smart thermostat that remembers to turn the heat down when you go out; a connected lock you can unlock remotely to let your nan in when you're running late; a robotic vacuum cleaner to do the floors when you can't be bothered… These are all top inventions, but is that really the future of our homes? Can't they be any smarter?

Yes, they can.

Over the next decade, smart connected technology in our homes will transition from being a novelty and nice-to-have to a necessity.

The most profound improvements will come from the ways in which this smart tech can free up our money, energy, and most importantly our time. In other words, our homes will start taking care of us all.

Ten years ago, there were no video doorbells, no Amazon Alexa or Apple Siri voice assistants, and the Nest Learning Thermostat was still a good three months out from being unleashed on an unsuspecting public. The smart home was still just something for the uber rich or those who really liked to clap their hands – even the iPhone was still a toddler.

In the ensuing decade, innovation has proceeded at a breakneck pace, and our homes are moving from analogue to digital in what feels like the blink of an eye.

Today, you can no longer buy a 'dumb TV' and the question "Should we put a Wi-Fi chip in that?" appears to only have one answer.

As the great Internet of Things comes online, what are the key technologies that will shape our homes over the next decade? We talked to leading experts and innovators in the field to discover just what our homes are going to be capable of in the year 2030. Find out what they say over the following pages. ➤

AMBIENT COMPUTING WILL MAKE YOUR HOME DO YOUR CHORES

"Alexa, turn on BBC Radio 4." "Google, play *Paranoid Android*." "Siri, what's the weather like?" If our virtual assistants were real, they'd be sick of our bossy demands by now, but unfortunately, they can't read our minds. But what if they could? Not literally of course, but what if they could anticipate our every need to become a bit less Alexa and a bit more Alfred (or Jarvis, or Jeeves. Other imaginary butlers are available for this joke).

What if our virtual assistants could learn to anticipate that we like the radio on in the morning, but not at the weekend or not on Thursday when we head to the gym early? That's the promise of ambient computing. A combination of artificial intelligence and its subset, machine learning, ambient computing is a key technology in the evolution of the smart home.

It's the point where a computer no longer needs direct input from you and instead it relies on your interactions with your surroundings to determine what to do next. In its simplest form, ambient computing is a technology that's always available, but you never know is there. When you leave your house in the morning, your AI-powered home turns off the heating, shuts off

"MACHINE LEARNING HAS TRANSFORMATIVE POTENTIAL WHEN IT COMES TO SENSING PATTERNS AND AUTOMATION"

Radio 4, arms the alarm system, and starts the robot vacuum. It takes away the responsibility of these chores from you and puts them onto your home.

"The concept of ambient computing is our north star for all of our devices and services connected to Alexa," says David Shearer, vice president of smart home at Amazon. "We want to increase Alexa's utility and shift the cognitive burden for complex tasks from the customer to Alexa."

Amazon's vision for the smart home goes beyond using voice commands to control devices to understanding what state the home and its devices should be in and then adjusting them according to what the user wants, says Shearer.

This may be a step too far for some, posits Daniel Knight, chief technology officer of Hiro, a UK-based insurance company focused on the value of smart home devices in protecting your home from disaster.

"The smart home is, and will continue to be, about convenient, informed control rather than just giving over to this artificial brain that's going to do everything for you," he says. "But there are isolated examples of AI that I see being able to effectively learn your preferences and really be game changers in your home."

The smart fridge is one such application. Long the butt of many jokes about the Internet of Things, an artificially intelligent fridge that can automatically create an inventory your food,

RING, GETTY IMAGES

order supplies you're running low on, and plan your meals for the week based on you and your family's nutritional needs will be commonplace by 2030.

"Planning meals and shopping is huge time suck," says Knight. "An appliance that uses cameras and/or weight-sensing shelves combined with a sophisticated enough AI is entirely capable of this type of interaction in the next decade." The technology is already here, he says, it's just waiting on improvements in the sensory inputs to help the AI interact with the right data.

However, the big challenge with machine learning is user trust.

"Machine learning has an enormous transformative potential when it comes to sensing patterns and automation," says Tony Gjerlufsen, head of technology at SPACE10, a research and design lab funded by IKEA to devise solutions to some of the major shifts expected to affect people and the planet. "[But] machine learning requires data and in the context of homes, much of that is considered private and intimate. It's ultimately up to the companies to prove themselves as sincere and dependable and that takes time. In the end, it's all down to trust."

Whether we give ourselves over to our smart homes in exchange for the convenience of having everything done for us, or if we decide to settle for more control and slightly less benefit is a conundrum that will likely play out over the next 10 years.

"I see the purpose of a smart home to act as a kind of assistant," says Georgina McDonald, lead design producer at SPACE10. "I would want the home to know me well enough to assist me positively. Turn on the vacuum if I forgot to clean or turn off the stove." But she warns of the dangers in relying on technology. "The fear for me is that the smart home makes our intuitions dull, as someone is there constantly picking up after you or fixing your mistakes."

ABOVE LEFT Just a decade ago, there were no smart doorbells, but they've now become popular, particularly as the pandemic has necessitated more physical distancing at the front door

ABOVE Smart fridges were long the butt of jokes about the Internet of Things, but we'll be eating our words in 10 years' time when we've all got one in our homes

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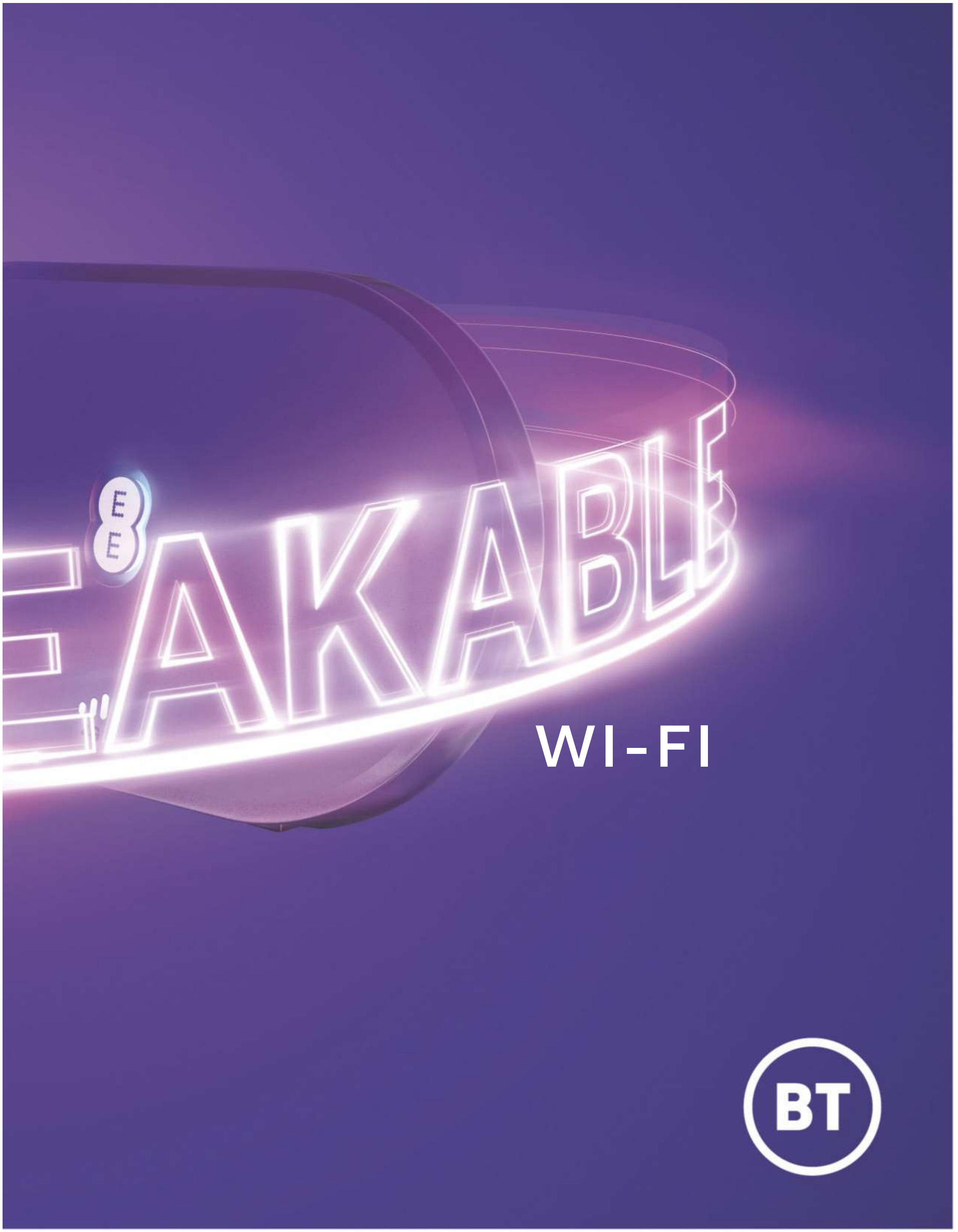

AKABLE
WI-FI

RADAR- AND SONAR-POWERED SENSORS WILL HELP KEEP YOU SAFE AND SOUND

Ambient computing relies on data points to understand your needs and that data comes from sensors. The more data the smart home has, the more context it can create, and the smarter it can be. Smaller, cheaper, lower powered, more robust sensors make developing smart home tech easier and more scalable, plus smarter sensors provide more context.

"The big advancements are going to come as we have more data," says Siminoff. "But if you just give someone a lot of data without any context or without really analysing it for them, then they're not going to use it, which means that it doesn't matter."

But no one wants to install hundreds of sensors or dozens of cameras in their homes, Instead, fewer, smarter sensors will give us a clearer picture of what's happening in our homes so that we – or the AI powering our home – can react appropriately.

Two somewhat surprising technologies doing this are radar and sonar. Where a single camera or sensor might tell you there is motion in your home in a particular area, radar can show you a 'picture' of your whole home in an instant. "Radar is faster," says Siminoff, whose company Ring just released two new outdoor cameras that use radar-based 3D motion detection. "If I can see my whole property and where everything is in two seconds I can make the right decision, because I have this three-dimensional context," he adds.

Radar is also being used to see inside the home without actually seeing anything at all. The idea of having internet-connected cameras inside our homes can be unsettling, yet the benefit of being able to check in on a pampered pet or make sure your grandpa is okay is compelling. One company, Vayyar, has developed a camera-free, radar-based 4D-sensing technology that can automatically detect if someone falls and will then call for help. The technology can also use machine learning to analyse a person's movements and identify unusual patterns over time – such as if someone hasn't got out of bed or has made more trips to the bathroom than usual, without ever physically watching them.

Sonar is also being used to see inside our home's infrastructure to identify problems before they become disasters. Krystian Zajac, founder of smart tech start-up Hero Labs, has developed a smart, ultrasonic flow meter with an integrated shut-off valve that will warn you if there's a leak in your home and can automatically switch off the water.

"Water leaks are the number one cause of property damage in the UK, costing the insurance industry more than fires and theft combined," he says. The device uses ultrasonic technology to detect low flows and employs machine learning to distinguish between different appliances in your home. This lets it build a virtual picture of what's happening in your pipes. Other sensors in the device, such as temperature and pressure sensors, add more context to alert you to a potential leak or frozen pipe before it becomes a disaster.

Putting sensors inside infrastructure will be commonplace by 2030, according to Siminoff. "You can easily plot out that in 10 years every single door comes with sensors already installed that tells you if it's open or closed, or if there's heat there, which could indicate a fire."

For example, Masonite, a global door manufacturer, recently developed a power management and connectivity module that can turn a front door into a 'smart door'. In addition to being pre-wired for smart locks and video doorbells, Masonite's door will also have built-in motion-activated lighting and a sensor that can track whether it is open or shut. The company also has plans for an interior door that can automatically shut if it senses fire, helping to protect you from smoke inhalation.

HERO LABS X2, GETTY IMAGES

LEFT Smart meters are clever, but they'd be even better if they could automatically help you reduce energy use

BELOW LEFT Hero Labs has developed a system that analyses flow rate in your water pipes and can detect leaks, slow flow or burst pipes, and will switch off the water supply to avert any disasters

SMART ENERGY WILL MAKE YOUR HOME A CLEANER, GREENER MACHINE

"Smart homes have the potential to automate, save money and save carbon," says Brian Horne, a consultant at the Energy Saving Trust. "At the moment, some so-called smart systems are just remote controls." In the very near future, however, your smart, connected home could become a crucial cog in the wheel that powers the green energy revolution.

British homes are one of the biggest contributors to the UK's carbon footprint, responsible for 25 per cent of the nation's CO_2 emissions. To help us reach net zero by 2050, a dramatic shift is needed. And it could all start with a Wi-Fi chip in your tumble dryer.

While smart thermostats can save some energy by turning your heating down if your home is poorly insulated, it's a token gesture at best.

The real benefit of the smart home comes from energy management. "Some of the biggest innovations in the home will be around helping people manage and reduce their energy use," says Geraldine de Boisse, vice president of innovation at Bulb, the UK's largest green energy supplier.

The key technology here is 'demand side response', or perhaps a better term is 'smart energy'. This is the act of using energy intelligently, employing technologies such as artificial intelligence and machine learning to allow the appliances in our home to communicate with the energy grid and help shift and reduce energy use.

A quarter of the average energy bill comes from the costs of transporting energy and balancing supply and demand. "If any large consuming appliances in your home can intelligently run when carbon intensity is low, or when the grid has excess, that's a really useful thing," says Knight, who worked on Samsung's plan for connecting its appliances to the energy supply system. "It doesn't help us generate more energy, it doesn't help us use less energy, but it helps us smooth out those peaks and troughs that make energy management so costly."

As we move toward net zero, electricity use is going to increase. More of us will have electric vehicles and use electric heat pumps for heating to ➤

"IF ANY LARGE CONSUMING APPLIANCES IN YOUR HOME CAN INTELLIGENTLY RUN WHEN CARBON INTENSITY IS LOW, OR WHEN THE GRID HAS EXCESS, THAT'S A REALLY USEFUL THING"

Electric vehicles may play a key role in how our homes use energy

reduce our dependency on oil and gas.

A recent white paper from the Department for Business, Energy & Industrial Strategy lays out how smart, connected appliances that can talk to the energy grid, combined with a decentralised, interconnected energy supply system, will not only help power the country in a cleaner way but will save you money, too.

Some of this technology is already here. Most new household appliances have Wi-Fi chips, or at least could come online with minor modifications. And as smart meters roll out across the country, people are starting to see how much energy their homes use, and can take advantage of energy tariffs that offer cheaper energy when demand is low.

Some tech is waiting for wider adoption. Electric vehicles are poised to be a key technology in how smart homes use energy. A single car can provide gigawatts of battery storage just sitting in your driveway. This is energy you can store for when you need it or export it to the grid and get paid for it. "This so-called 'vehicle-to-grid technology' is something we're working on for the future," says de Boisse.

Once the systems are in place, the smart home will play a key role in a decentralised energy grid. "The next step is for people to give some control to their supplier and allow them to control the flow of power to their devices like electric vehicles, heat pumps and ventilation systems to avoid peak periods, and charge or operate when it's cheapest and greenest," says de Boisse.

All of this will again require a substantial amount of trust, a common theme when it comes to the smart home of the future.

"If we do get fully connected homes with appliances that talk to each other, that raises the question of do we want it to be fully automatic?" says Horne. "Is our data secure, and how far do we go? Ultimately, that should be a decision for the householder – smart homes should be about taking control of our lives, not giving it up."

AN ALWAYS-ON NETWORK WILL KEEP THE HOME CONNECTED

Today, it feels like there is one potentially fatal flaw in the smart home: us. If our appliances are going to talk to the grid, our front door chat with our doorbell, and our fridge check in with the supermarket, they will need to be online all the time. This means we need to manage our home networks, change passwords, allow firmware updates and run our homes like a network administrator. Nobody wants that.

"If you put a dishwasher with a Wi-Fi chip in it into a home, the network is free to the manufacturer, but the cost is that the customer has to keep that on the network," explains Siminoff. "Every time they change their Wi-Fi password, are they going to update their dishwasher? It turns out, they won't."

To keep devices connected we will need an always-on network, like the Wide Area Network that the Department of Energy & Climate Change has in place, to allow smart meters to talk to energy suppliers. This will allow your connected tumble dryer, electric vehicle charger and smart thermostat to stay online if you sell your house and someone else moves in.

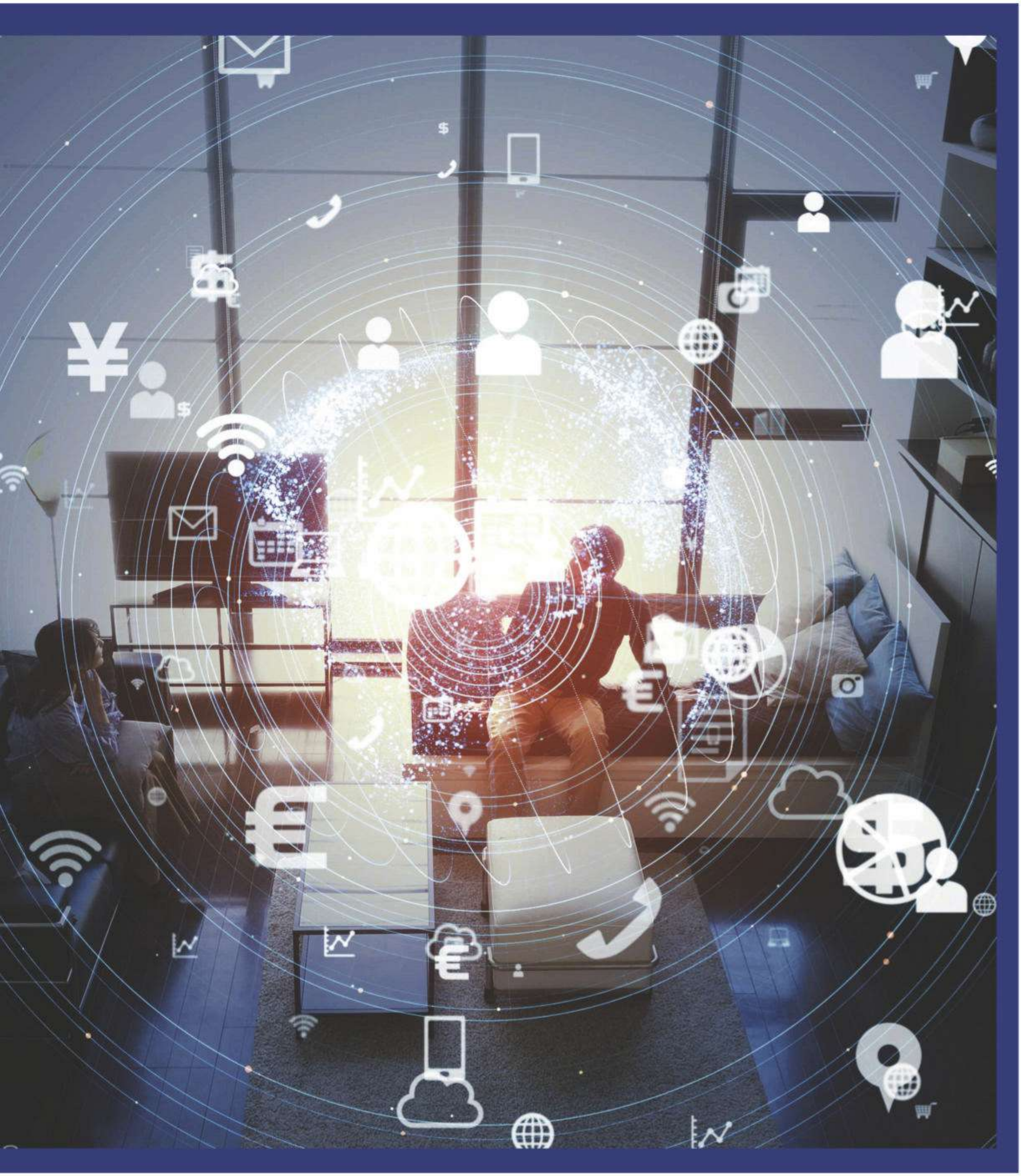
"5G IS POISED TO BE A NETWORK THAT CAN SIGNIFICANTLY IMPROVE THE SMART HOME, WITH ITS LOWER LATENCY, GREATER CAPACITY AND HIGHER SPEEDS"

One solution could be 5G. The successor to 4G cellular communication, 5G is poised to be a network that can significantly improve the smart home, with its lower latency, greater capacity and higher speeds, plus its always-on capability. By 2030 the technology will be widespread enough to at least be a factor in keeping UK smart homes online.

The downside of networks like 5G however, is that they need a lot of power. That's fine for an always plugged-in appliance, but not so useful for small, battery-powered wireless devices such as sensors.

This is where low-power, wide-area networks such as Semtech's LoRa and Amazon's Sidewalk could improve connectivity both inside and outside the home. "To expand device coverage throughout and beyond the home, we're investing in long-term technologies like Amazon Sidewalk, a secure, shared network that helps devices work better in and around your own home, and in the community where Wi-Fi doesn't reach," says Shearer. "Ensuring devices can connect at greater distances and work together regardless of which company made the device, is the way we will help connect the next billion smart home devices." SF

ALAMY, GETTY IMAGES



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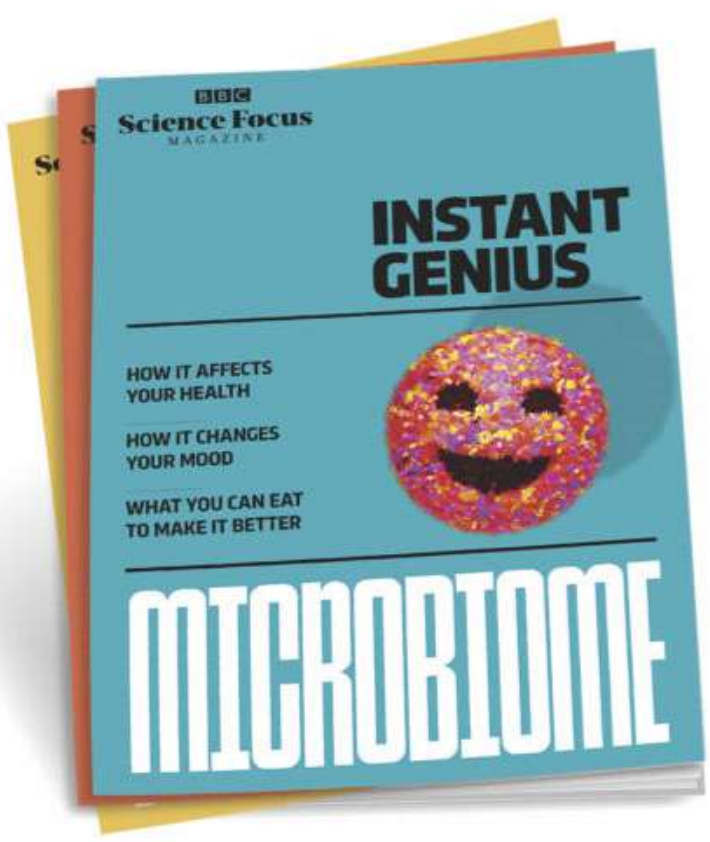

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... HOW LONG DID IT TAKE THE DINOSAURS TO GO EXTINCT?
... WHY DOESN'T MY HEART GET TIRED?
... WHY DO I TURN INTO A WEEPING WRECK WHEN I'M HUNGOVER?
... HOW CAN I SEE THE MILKY WAY?
... CAN WE TURN POISONOUS PLANTS INTO EDIBLE CROPS?
... WHAT IS THE AVERAGE COLOUR OF THE UNIVERSE?
... WHAT WOULD HAPPEN IF TWO GAS PLANETS COLLIDED?
... HOW DO DESERTS FORM?
... IS THERE REALLY A SOUND THAT MAKES YOU POOP YOURSELF?

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Chemistry expert

DR CHRISTIAN JARRETT
Neuroscience expert

DR NISH MANEK
Medical expert and GP trainee

LUIS VILLAZON
Science and technology writer

ILLUSTRATION: DANIEL BRIGHT

EMMA ELDRIDGE, WIMBLEDON

WHY DO I ALWAYS WALK INTO A ROOM AND FORGET WHAT I'M DOING?

Fear not, you're far from the only one to have had this rather unsettling experience.

Since 2006, psychologists at the University of Notre Dame in Indiana have been investigating what's become known as the 'doorway effect'. In one study they used a virtual reality setup to show that their volunteers' memory of items in a room was diminished once they walked through a doorway into another room.

The researchers propose a three-part explanation: our memories are divided into episodes; we find it trickier to recall information from earlier episodes; and, critically, when we walk through a doorway, it creates a new episode or 'event boundary' (thus making it more difficult to recall our purpose, which was stored in the previous memory episode). These results have implied there's something almost magical about the effects of doorways on our brains. However, this year a team at the University of Queensland painted a more nuanced picture. They found that passing through doorways that joined identical rooms mostly didn't impact memory – perhaps because there wasn't enough of a changed context to create a significant event boundary. It was only when these researchers distracted their volunteers with a simultaneous secondary task that the doorways between identical rooms affected memory.

The Queensland team said this chimes with everyday experience in that it's mostly when we're distracted, with our mind on other things, that we're inclined to arrive in a room and forget what we came for. It also suggests the doorway effect is more likely to occur when there is a significant change in context – for instance, if you leave your living room for the garden. The new results also point to a potential cure – try to stay focused on your purpose when you pass through a doorway on an errand (failing that, you could always make a note on the back of your hand). ***CJ***

NATURE'S WEIRDEST CREATURES...

SPIDER-TAILED HORNED VIPER

By the time you see the spider-tailed horned viper, it's probably too late. At least if you're a bird, that is. Its mottled beige and white body is brilliantly camouflaged against the shimmering backdrop of gypsum and limestone rocks in its natural habitat in Iran – all except for the very tip of its tail, which has evolved into an elaborate lure for unsuspecting birds.

As the name suggests, spider-tailed horned vipers have a unique growth at the tip of the tail that is covered in long thin scales resembling spider legs. They expertly wiggle this bait around to mimic the skittering movements of a spider, tricking onlooking birds into thinking they've found a tasty meal. But when a bird swoops in to peck at the spider, the snake is ready to strike within a fraction of a second.

However, only migratory birds seem to be fooled by the viper's elaborate lure, suggesting local birds may have become wise to the trick.

Many snake species shake the tip of their tail before striking, and rattlesnakes famously have a rattle-like tail growth to distract prey, but the spider-tailed horned viper has really taken these ideas and run with them (well, slithered). Despite them seeming similar to a casual observer, the viper's spider-lure is formed from soft tissue, while rattlesnake rattles are created from fused bone, so they likely evolved independently. ***CA***

ALAMY, SCIENCE PHOTO LIBRARY, GETTY IMAGES ILLUSTRATIONS: DANIEL BRIGHT

OSCAR LANG, GLASGOW

HOW LONG DID IT TAKE THE DINOSAURS TO GO EXTINCT?

When the Chicxulub asteroid hit the Earth 66 million years ago, various effects combined to kill the dinosaurs. No doubt many dinos, particularly those within 1,600km or so of ground zero, would have died instantaneously. Others would have died over the next few hours, days and weeks from the heat pulse, tsunamis and earthquakes. The final nail in the coffin was a years-long nuclear winter followed by millennia-long global warming. By about 25,000 years after the asteroid, there are well-dated fossil assemblages devoid of dinosaurs, but overrun with their inheritors: mammals. ***SB***

LOLA MYERS, CARDIFF

WHAT IS THE AVERAGE COLOUR OF THE UNIVERSE?

In a 2002 study, astronomers found that the light coming from galaxies (and the stars within them) – alongside all the visible clouds of gas and dust in the Universe – when averaged, would produce an ivory colour very close to white. They named this colour 'cosmic latte'.

The 'beigeness' of the Universe is because there are slightly more regions that produce red, yellow and green light than those that produce blue. Averaged over the entire sky, however, this beige colour is diluted and appears almost, but not entirely, black. ***AGu***

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

WHY DO I TURN INTO A WEEPING WRECK WHEN I'M HUNGOVER?

Hangover anxiety (or 'hangxiety') has many contributing factors. One of the effects of alcohol is to increase levels of GABA (gamma aminobutyric acid), which sends chemical messages through the brain to inhibit the activity of nerve cells, initially creating a calming effect. As you carry on drinking, alcohol also starts reducing an excitatory transmitter called glutamate, which often leaves you feeling less anxious. So far, so good. But this doesn't last. As the body registers this new imbalance in brain chemicals, it tries to correct it. This means when you stop drinking, you're soon left with unnaturally low GABA levels and a spike in glutamate, which leads to heightened anxiety.

Glutamate is also needed to lay down memories, so another contributing factor to hangxiety might be ruminating on the things you can't actually remember saying or doing from the night before.

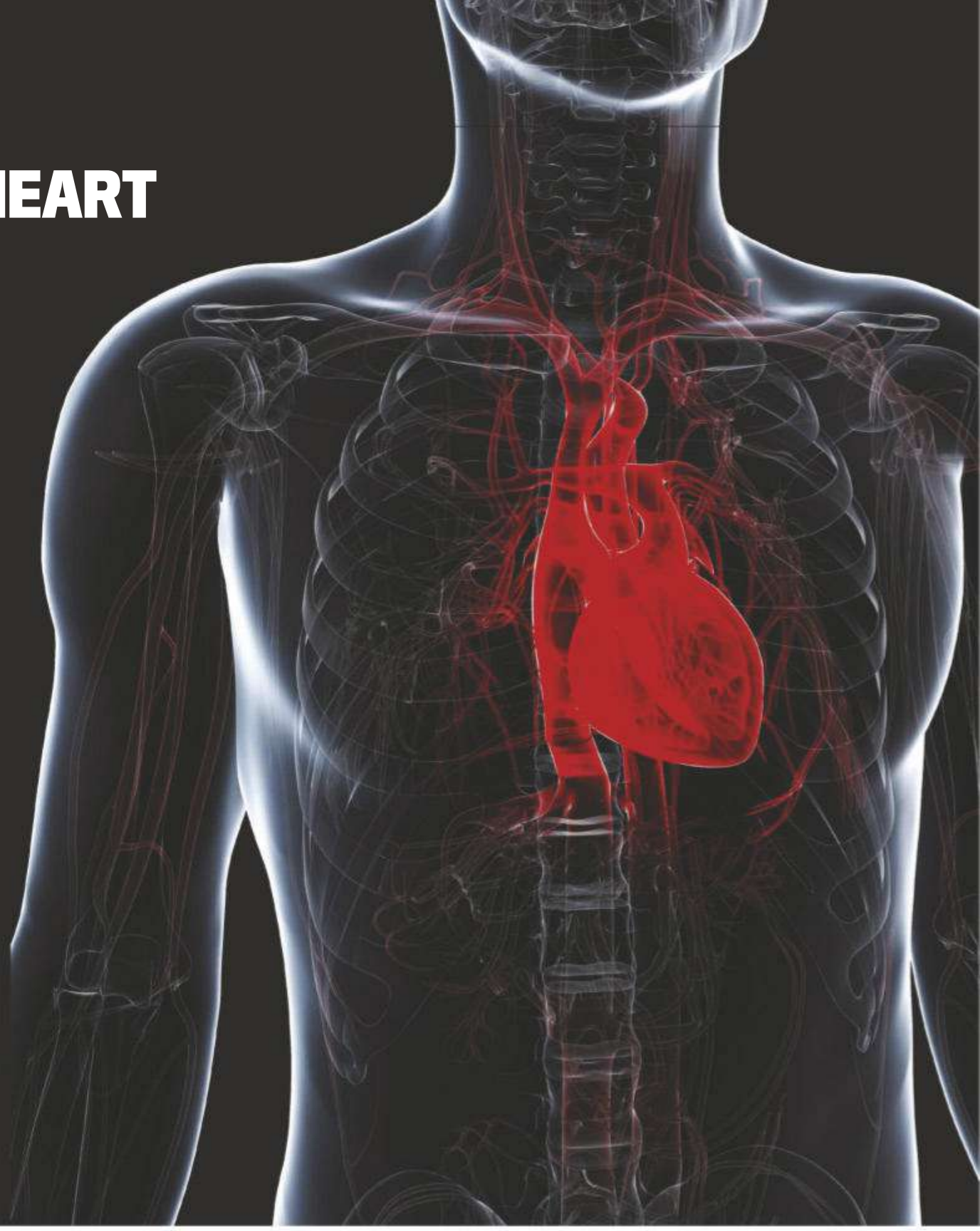
Sleep disruption is also a factor. Alcohol is known to reduce REM sleep, which is essential for cognitive function. This means drink decreases overall sleep quality, which can exacerbate anxiety and low mood.

If this isn't resonating, hangxiety isn't experienced by everyone to the same degree. One study in the journal *Personality And Individual Differences* found that shyer individuals reported higher levels of anxiety the following day than more confident people.

But what can you do if you're one of the unlucky ones? Well, keeping hydrated, taking painkillers, resting and deep breathing exercises can help to get through the symptoms. But the only real solution is to not drink alcohol in the first place. Just remember that 'happy hour' might well lead to a lot of unhappiness in the cold light of day! ***NM***

BEN MORRIS, YORK

WHY DOESN'T MY HEART GET TIRED?



Your heart is an incredibly powerful organ. Every day it beats about 100,000 times. Imagine the energy takes it to squeeze a tennis ball – that's not far off the force your heart is using each time it beats to pump blood around your body. So, with that many reps each day, why doesn't it burn out? While your heart *is* a muscle, it's not quite the same as your skeletal muscles – such as the biceps and quads – that are attached to your bones. This is primarily because the heart is made of cardiac muscle, consisting of special cells called cardiomyocytes. Unlike other muscle cells in the body, cardiomyocytes are highly resistant to fatigue. True, cardiomyocytes are primarily powered by mitochondria (the energy house of the cell), similar to your other muscles. However, cardiomyocytes have as much as *10 times* the density of mitochondria, skyrocketing their energy output. The cardiomyocytes have also evolved to have an enhanced blood supply, being better than ordinary muscle cells at extracting oxygen from the blood. Plus, the heart has another secret weapon: it's flexible in terms of fuel, able to consume glucose, free fatty acids and lactate.

So, why aren't all muscles made of cardiomyocytes? For all their benefits, cardiomyocytes contract without nerve supply, making them incapable of voluntary and purposeful movements. But when it comes to beating constantly and without tiring, your heart has evolved to do its job brilliantly – it has no time for DOMS (delayed onset muscle fatigue) after a hard workout. Which is fortunate, because, when it comes to your cardiac muscles, rest days are not an option. ***NM***

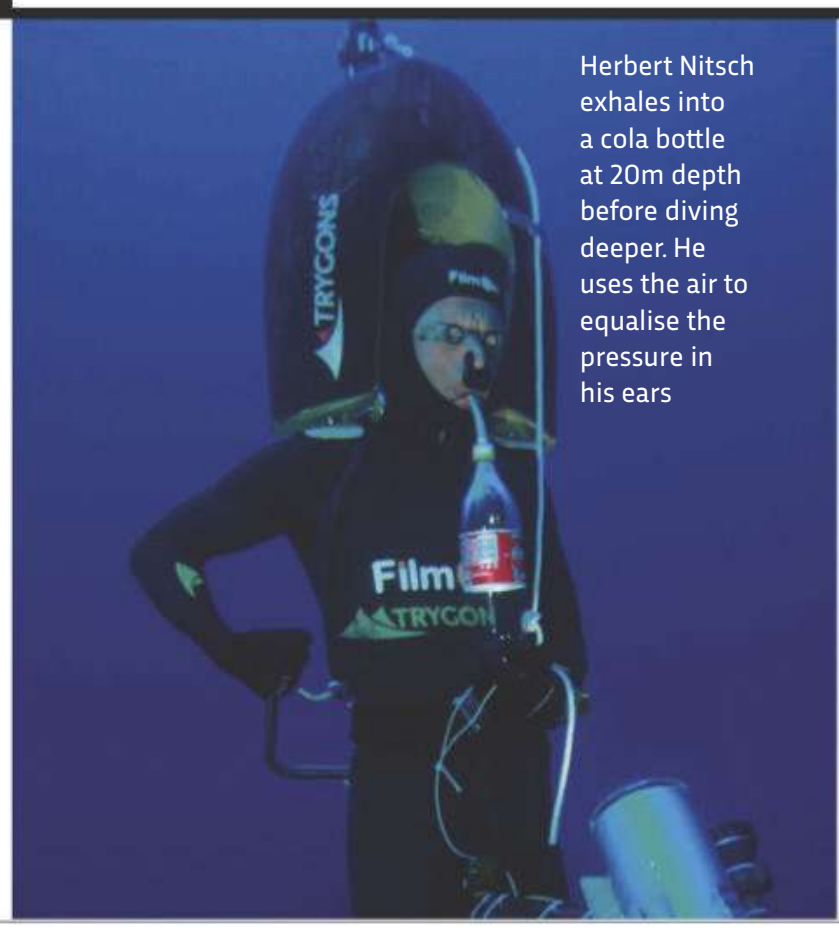
TOP TEN

SOURCE: AIDA HTTPS://WORLDRECORDS.AIDAINTERNATIONAL.ORG/NOLIMIT

DEEPEST FREEDIVING WORLD RECORDS

Fancy picking up a new sport all the family can enjoy? Freediving isn't for you. Or, specifically, no-limits freediving in which an athlete plummets underwater as deep as possible, using any method, in just one breath. It's a sport that has seen divers ride hundreds of metres towards the ocean floor on a weighted sled at speeds of over 5m/s. The immense water pressure at the depths they reach is enough to crush WWII era submarines. If the human torpedo somehow doesn't pass out due to nitrogen narcosis at this depth, they then activate a self-inflating balloon to shoot to the surface, where they may suffer decompression sickness and brain damage.

Ping pong it ain't. Not only has no-limits freediving seen many deaths, but no official diving body will now ratify any new world record attempts over safety concerns.



Herbert Nitsch exhales into a cola bottle at 20m depth before diving deeper. He uses the air to equalise the pressure in his ears

1 **HERBERT NITSCH**
AUT, 2007
214M

2 **HERBERT NITSCH**
AUT, 2007
185M

3 **HERBERT NITSCH**
AUT, 2006
183M

4 **HERBERT NITSCH**
AUT, 2005
172M

CROWDSCIENCE

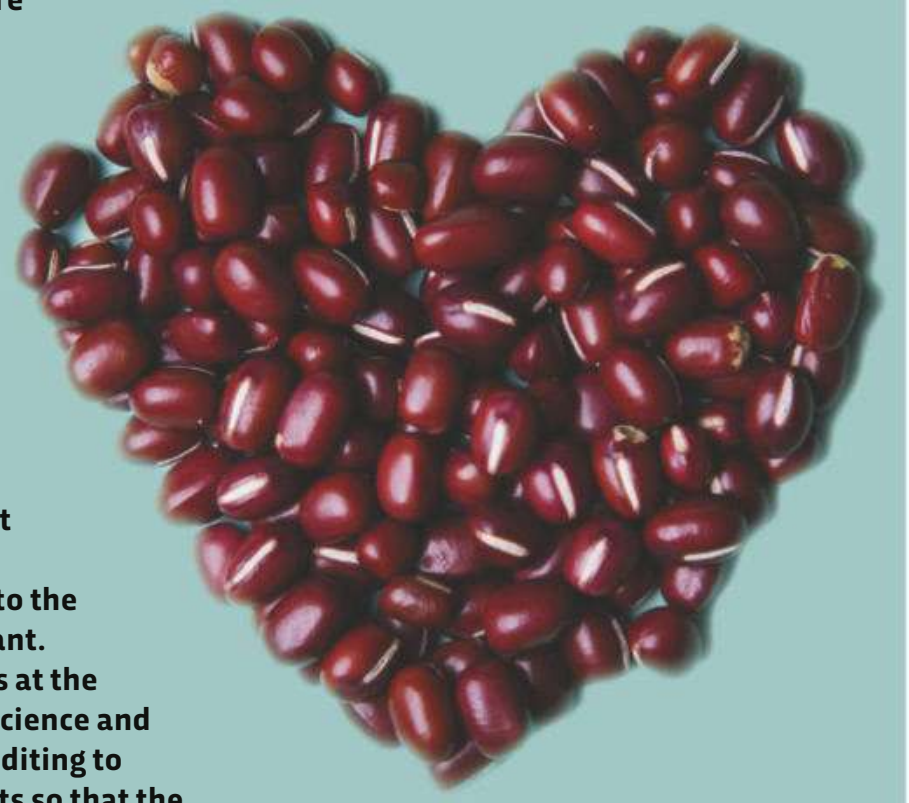
Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

COULD WE TURN POISONOUS PLANTS INTO EDIBLE CROPS?

We actually already eat several plants that are poisonous. Kidney beans, for example, contain the toxin phytohemagglutinin and just five beans are enough to give you vomiting and diarrhoea – unless you cook them first.

Cooking is a human innovation that has added lots of new plant species to our diet by destroying the toxins in them. Plants have evolved to synthesise these toxic chemicals in order to discourage animals and insects from eating them, but farmers are constantly looking for ways to produce tastier crops by lowering the concentrations of these chemicals. Thanks to this, modern varieties of grapefruit, Brussels sprouts and aubergine are now much less bitter than they were 50 years ago. But there is a balance to strike between their taste on the plate and how attractive they are to agricultural pests in the field. The ideal would be a plant that keeps the pests away until harvest time and then ripens into something more appetising.

Tomatoes already do this – the toxic alkaloid in green tomatoes naturally breaks down as the fruit ripens – but modern gene-editing techniques are taking this a step further. Canola or rapeseed is grown commercially for its oil but the seed husks were previously discarded due to the toxins produced by the plant. However, in 2012 scientists at the Norwegian University of Science and Technology used genetic editing to reprogramme canola plants so that the toxin levels faded away as the seeds matured. The pressed seeds can now be turned into a protein-rich flour that is used in cereal bars and vegan meat substitutes. *LV*



ALAMY X4, GETTY IMAGES X4

5
LOIC LEFERME
FRA , 2004
171M

6
LOIC LEFERME
FRA , 2002
162M

7
TANYA STREETER
USA , 2002
160M

8
UMBERTO PELIZZARI
ITA , 1999
150M

9
LOIC LEFERME
FRA, 1999
137M

10
MANDY-RAE CRUICKSHANK
CAN, 2001
136M

ASTRONOMY FOR BEGINNERS

Vega
Deneb
Milky Way
Altair
Locate the Summer Triangle high up, south at 2am on 1 July, 1am on 15 July and midnight on 31 July (all times BST)

HOW CAN I SEE THE MILKY WAY?

WHEN: SUMMER (MAY-OCTOBER)

In 1994, a power cut in Los Angeles plunged the city into darkness. With the sudden lack of light pollution, a strange glow appeared in the night sky, causing some concerned citizens to call the emergency services. The silvery cloud they were seeing for the first time? Their own galaxy.

Those LA residents aren't alone in not seeing the Milky Way before. A third of people around the world can't see it because of light pollution. But the good news is, if you travel somewhere dark and let your eyes adjust, you can still see the magic of the Milky Way.

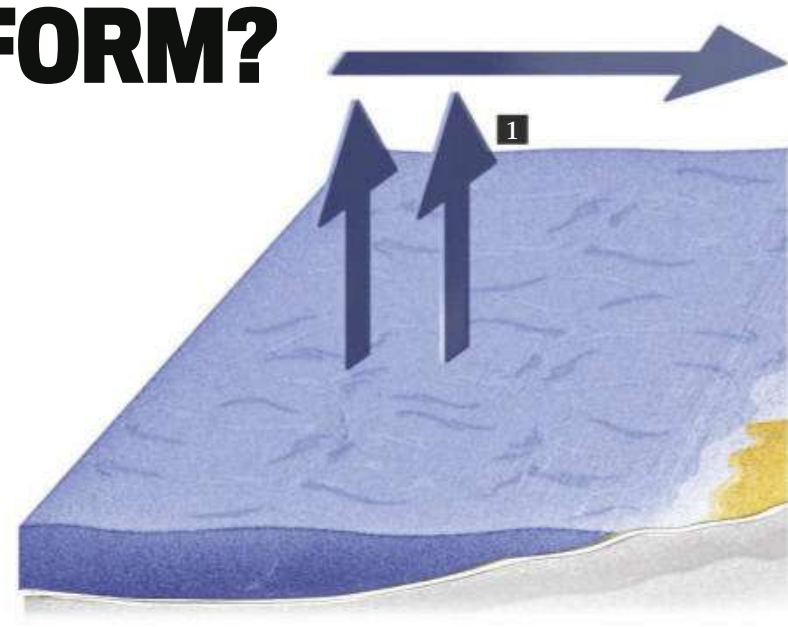
Our Solar System is part of the Milky Way, which is a spiral galaxy. We sit on one of the arms of the Galaxy, and in the centre there are millions of stars. From Earth this looks like a band, densely populated with stars, that stretches across the sky. The Milky Way is visible from May to October, and in July it's visible as soon as it gets dark.

To see the light from the Milky Way, it's best to minimise light pollution as much as possible (get away from streetlights, if you can safely). Once in the darkness, let your eyes adjust for at least 40 minutes.

Pick a night with little to no moonlight, to minimise glare from the lunar surface. On 10 July there will be a new Moon, so try to look for the Milky Way as close to this day as possible.

To help find the Milky Way, we can use an asterism called the Summer Triangle. This is made up of three bright stars located high in the sky in July (Vega, Deneb and Altair). To find the Summer Triangle, just look high to the south and southeast in the sky. The Milky Way runs through Deneb and Altair. ***AB***

HOW DO DESERTS FORM?



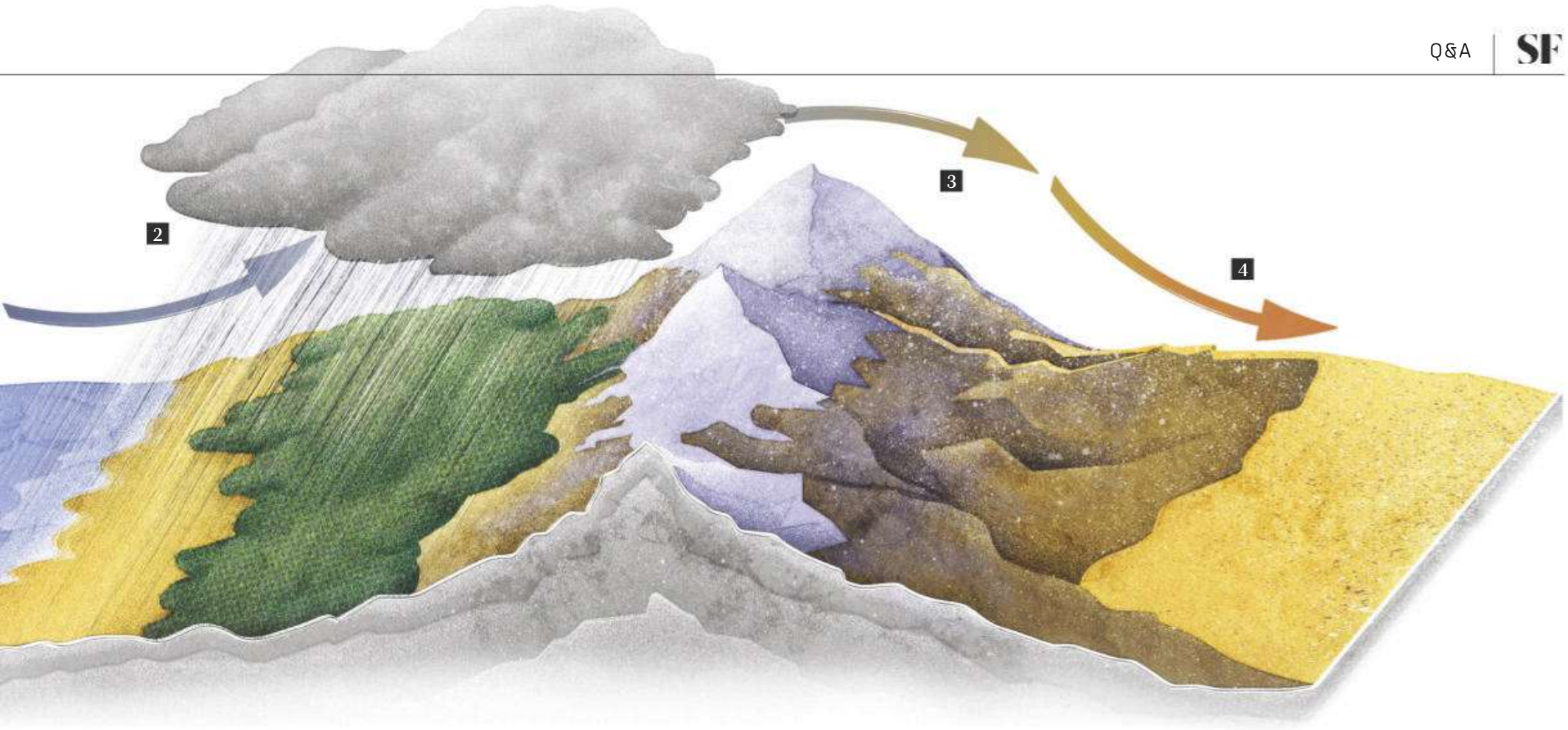
Mountain ranges can create deserts by preventing moist air from reaching certain areas. Known as the 'rain shadow' effect, this phenomenon has played a part in the formation of many arid landscapes, including the Mojave, Gobi and Atacama deserts. ***AFC***

NABIL BENDRIMIA, LONDON

IS THERE REALLY A SOUND THAT MAKES YOU POOP YOURSELF?

The enduring legend of the 'brown note' – a sound frequency so low that its resonance through the human body causes spontaneous, uncontrollable pooping – is thankfully no more than a legend. The origin of this hilarious, if unsettling, myth appears to be a spoof article published in 1974, which described a giant horn that apparently gave the entire audience diarrhoea with a rendition of the national anthem at its unveiling in 1850.

However, scientists have tested the effects of different sound frequencies on the human body and found no evidence for the infamous brown note. ***CA***



1 EVAPORATION
Warmed by the Sun, water evaporates from oceans and other bodies of water, entering the atmosphere as water vapour and forming clouds. This warm, moist air is swept inland by winds.

2 UPWARDS WINDS
If the prevailing wind passes through a mountain range, warm, moist air is forced upwards. As it rises, it expands and cools. As colder air is not able to carry as much moisture, the water condenses out, falling as rain or snow. This is known as orographic precipitation, and typically supports lush vegetation on the upwind side of the mountain.

3 WARM AIR DESCENDS
Stripped of moisture, the cool, dry air passes across to the other side of the mountain range, warming up again as it descends. On this side of the range, the lack of moisture prevents cloud formation, creating a dry area commonly called a 'rain shadow'.

4 LOW HUMIDITY
A region is officially classified as a desert when rainfall is under 250mm per year. Without vegetation, any soil or organic matter is swept away by winds, often leaving behind sand and rocks. Low humidity also means it can get extremely hot when the Sun is shining, but very cold at night.

QUESTION OF THE MONTH

MARK BUCKMASTER

WHAT WOULD HAPPEN IF TWO GAS PLANETS COLLIDED?

Although orbital dynamics make it highly unlikely that two gas giants would collide, there's a small chance that such an impact could happen during the formation of a planetary system. The result of a collision mainly depends on the speed and angle of impact. Head-on collisions would generally lead to a complete merger of the gas giants without any loss of material, either in their solid cores or in their gaseous envelopes. However, a higher speed head-on collision would likely lead to the loss of most of the envelope gas as the two cores merge. Very high speeds would completely fragment and destroy both planets.

Collisions that are not head-on (known as oblique collisions) can give different results. For instance, if the two cores avoid each other completely, both gas giants will lose a substantial fraction of their gaseous envelopes to space, but will not merge. If the cores collide at an angle then the planets may or may not merge, but in all cases a large amount of the gaseous envelope will be lost. Very oblique collisions do not disrupt the planets at all and both would continue on almost the same orbits without losing any mass. Oblique impacts between gas giants can lead to changes in their shape, or 'oblateness'. This has been proposed as a means of studying the early impact history of gas giants in other star systems.

Although there is no concrete evidence that Jupiter or Saturn formed from the merger of smaller gas giants, it is a possibility. Jupiter and Saturn have a higher fraction of heavy elements than the Sun, suggesting that one or both of them may have been formed by such a collision. ***AGu***

WINNER

Mark wins a **JLab TALK GO USB microphone**, worth £49.99. This light, compact mic has generous resolution, making it great for calls in the home office, as well as gaming, podcasts or voiceovers. It comes complete with volume control and a quick-mute button. It easily connects to your computer via USB and includes an AUX input for real-time listening. **jlab.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X2 ILLUSTRATIONS: DAN BRIGHT, PETE LAWRENCE

THE EXPLAINER

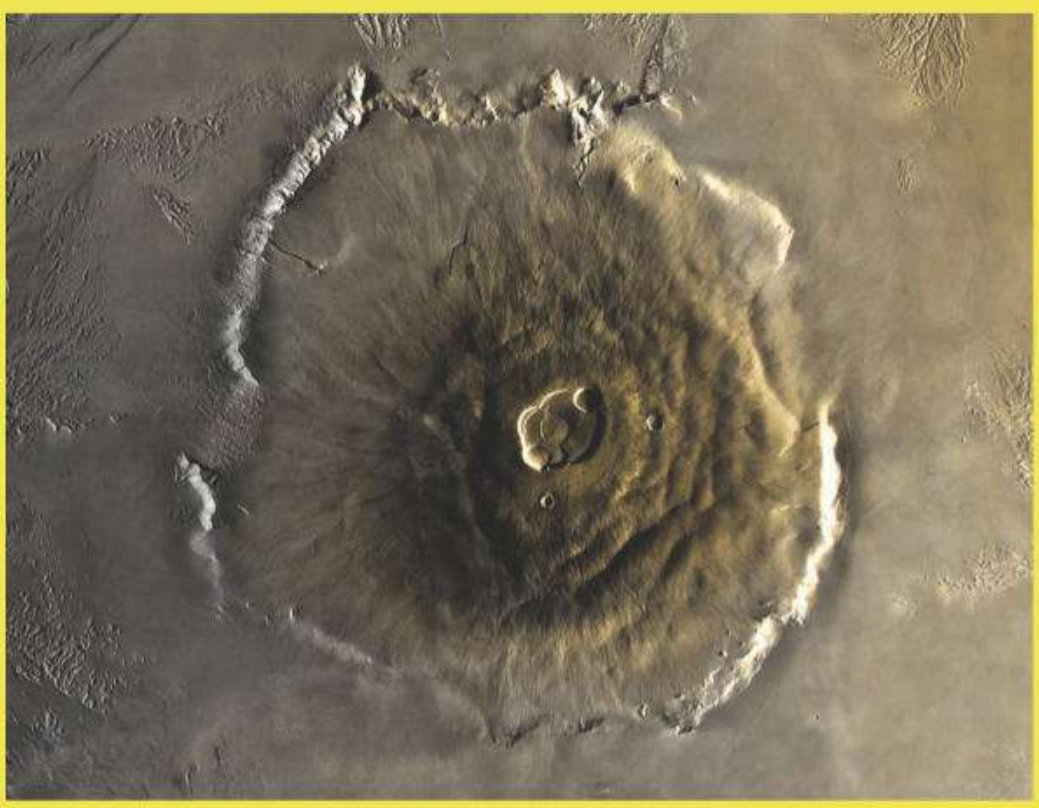
THE EXPLAINER: WHY ARE MOUNTAINS SO FORMIDABLE?

HOW DO MOUNTAINS FORM?

Most mountains owe their existence to the movement of tectonic plates, vast sections of the Earth's crust. Where two tectonic plates converge, they buckle and fold, resulting in the most common type: fold mountains. The Himalayas, for example, result from the Asian and Indian plates slowly colliding. Block mountains are created when the pressures between plates allow cracks (faults) to appear, with huge slabs of rock being thrust upwards.

Volcanic activity can also produce mountains. As a volcano erupts, the buildup of molten rock can form peaks. Sometimes, the rising magma can remain trapped underground, causing the surface to swell in a dome shape.

With tectonic plates typically moving just three to five centimetres per year, mountains slowly take shape over tens or hundreds of millions of years. The oldest mountain range in the world is the Barberton Greenstone Belt in South Africa, with some mountains estimated at 3.5 billion years old.



WHAT'S THE BIGGEST MOUNTAIN IN THE SOLAR SYSTEM?

Mars's Olympus Mons is often described as the highest mountain in the Solar System. One of many volcanoes on the Red Planet, it towers over its neighbours at 21.2km above the Martian equivalent of 'sea level', making it about two and a half times as tall as Earth's Mount Everest (8.8km). However, an unnamed mountain peak comes a strong second. Situated at the centre of a huge crater on the asteroid Vesta, it has a height of at least 20km. Its size is even more impressive when you consider that Vesta's diameter is only 530km. Determining a clear winner is challenging, partly because of the difficulties in establishing a reference height equivalent to sea level on Earth. For example, 'zero altitude', the equivalent of sea level on Mars, is often measured as the height in which temperature and atmospheric pressure would allow water to exist simultaneously in all three states: solid, liquid and gas.

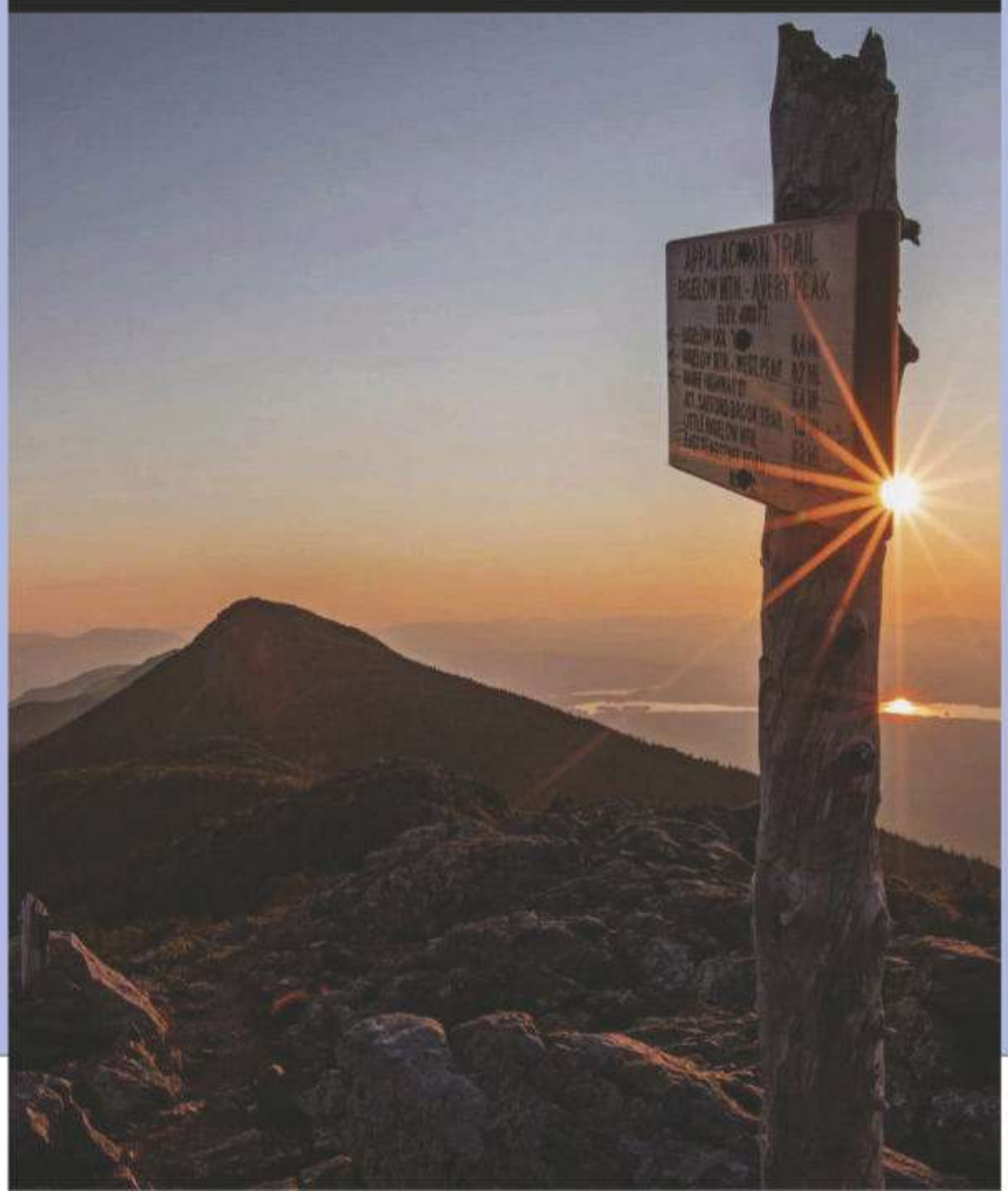
GETTY IMAGES X2, NASA/JPL, SHUTTERSTOCK, ALAMY

ARE MOUNTAINS GETTING TALLER?

Many mountain ranges are still growing under the continuing shift of tectonic plates. These include the Himalayas, which increase in height an average of 5mm per year. However, after an earthquake struck Nepal in 2015, some of its peaks shrank up to a metre.

In other regions, tectonic movement has slowed or ceased, such as the tectonic plates that produced the USA's Appalachian mountains, which are no longer converging. Instead, for the last 200 million years, weather erosion has been the main force shaping these mountains.

Other processes can also cause a mountain's height to change. Well, at least *appear* to change. Altitude is measured relative to the mean sea level in the local area – so the exact height depends on which local area is chosen as a reference point. While early measurements relied entirely on trigonometric calculations, nowadays these are assisted by GPS or gravitometers to evaluate altitude more precisely.



HOW DANGEROUS IS IT TO CLIMB EVEREST?

Over 300 people are known to have died scaling Everest since 1922. Injuries and bad weather can be deadly in this remote environment, and our bodies have not evolved to cope with low oxygen levels at high altitude. Altitude sickness can lead to fatal pulmonary or cerebral oedemas, which occur when the lack of oxygen results in leakage of fluid into the lungs or brain. To avoid this, mountaineers acclimatise in stages, allowing their bodies to adjust gradually. Above 8,000 metres, climbers enter 'the death zone' where the air pressure is so low that humans cannot survive for long periods without supplementary oxygen.

In 2019, high winds left just a few suitable days for climbers to attempt Everest's summit. Many were forced to wait their turn at punishingly high altitudes, amplifying the effects of exhaustion and altitude sickness. This led to one of the mountain's deadliest years ever, with 11 reported fatalities.

WHAT ANIMALS LIVE ON MOUNTAINS?

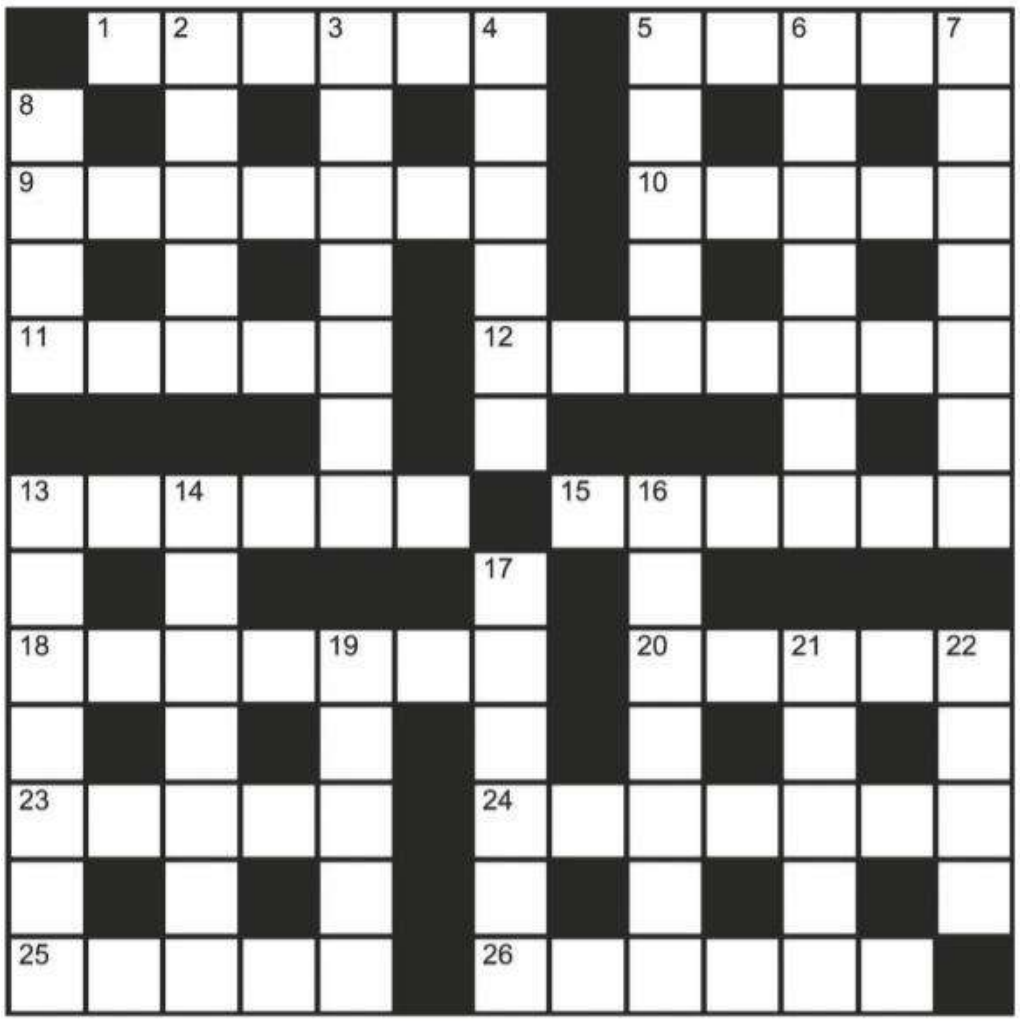
With scarce oxygen, high winds, freezing temperatures and strong sunshine, mountains are a hostile environment. Yet many animal species have adapted to make mountain peaks their home, evolving red blood cells that can absorb more oxygen. One of the most famous mountain residents is the snow leopard, which lives at altitudes of 3,000 to 5,000 metres in central Asia. Its prey include various species of mountain goats and pikas (tiny members of the rabbit family who are thought to be the highest dwelling mammals on Earth, sometimes found at altitudes surpassing 6,000 metres). Spotted at up to 7,000 metres, bar-headed geese fly over the Himalayas during their annual migration. Flying in such a thin atmosphere is difficult, but these large-lunged birds fly at night when the air is colder and denser.

Around 12 per cent of humans live in such habitats, and some people have also evolved to live at altitude – most Tibetans possess a genetic mutation that prevents their bodies from over-reacting to low oxygen levels.

by ALEX FRANKLIN-CHEUNG
Alex is a science and environment writer.

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Reliable outbuilding (6)
5 Drunken chat after head of broadcasting gets consignment (5)
9 Lettuce as a shipping hazard (7)
10 Gold rug returned to fortune-teller (5)
11 Small vegetable, glossy (5)
12 A no-good shelter outside a line (7)
13 Father's attempt at filo, say (6)
15 Equal to time and distance (6)
18 After games start, kittens twinkle (7)
20 Deity takes Georgia to be heathen (5)
23 Insults sailor getting employment (5)
24 Eccentric CIA operation is from the heart (7)
25 Time to tear into fashion (5)
26 Assembly of seat constructed, having directions (6)

DOWN

2 Article with yours truly as subject (5)
3 Tumbler has right to wave (7)
4 Heavy front, missing number (6)
5 Muscle and bravado initially overturning new conflict (5)
6 Fierce female to lock soldier back inside (7)
7 Dissident is present with twitch (7)
8 Notice the absence of a young woman (4)
13 Errand boy joins worker in parade (7)
14 Fit for arrest (7)
16 Sprain treated, taking one painkiller (7)
17 Commotion ruined a scarf (6)
19 Pace rated incorrectly (5)
21 Self-reproach at expensive coat, say (5)
22 Kiss part of the guitar (4)

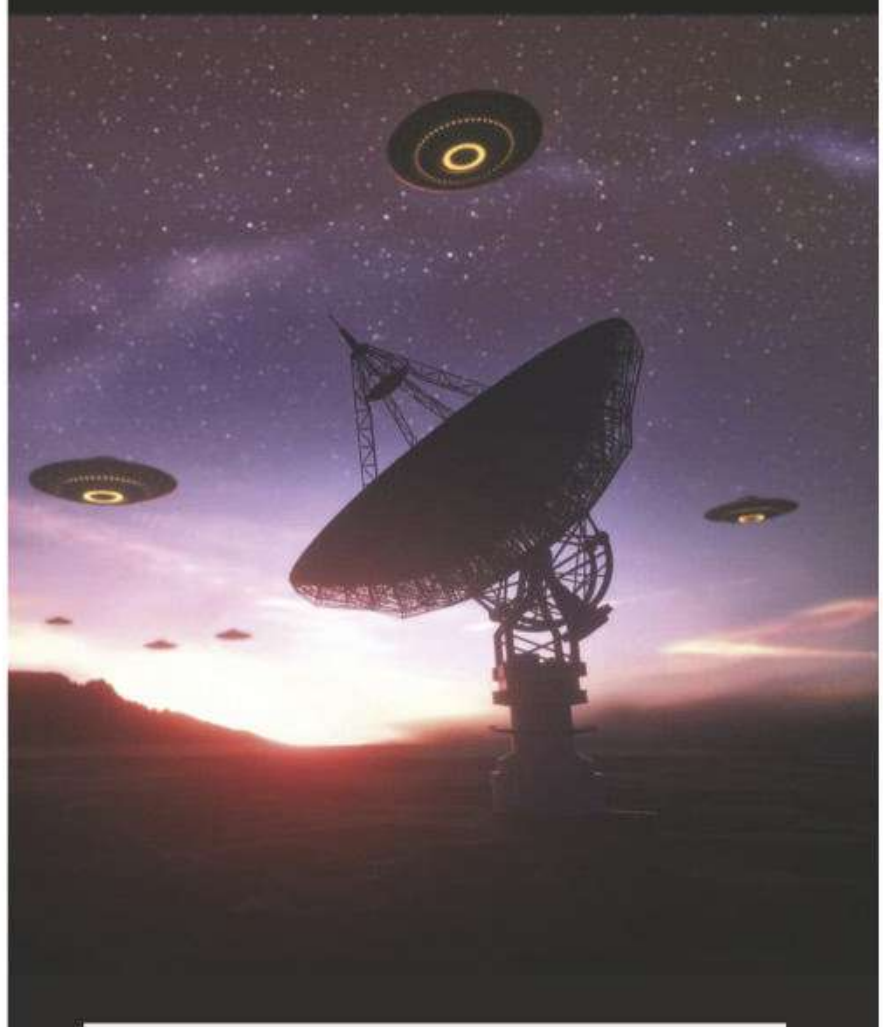
ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

SHOULD WE CONTACT ALIENS?



PLUS

WHAT SHOULD WE DO WITH DEAD BODIES?

We're running out of graveyard space.

OLYMPICS Q&A

How does the Fosbury flop work? Will we reach a point where sports records can no longer be broken?

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A SCIENTIST'S GUIDE TO LIFE

INDOOR AIR POLLUTION

CLEANING PRODUCTS... CANDLES... COOKERS... HOW MUCH DOES INDOOR AIR POLLUTION REALLY AFFECT US, AND WHAT CAN WE DO ABOUT IT? RESPIRATORY SPECIALIST **DR JONATHAN GRIGG** EXPLAINS ALL

INDOOR AIR POLLUTION IS WIDESPREAD.

It takes many forms, from the tiny particles that are emitted when we cook or clean, to the spores released by mould when it's damp, and the chemicals that are embedded in our furniture.

THE POSSIBLE IMPACT ON HEALTH IS CONCERNING.

Small particles that are inhaled can travel to the lungs and cause problems. Studies suggest that indoor air pollution is linked with an increased risk of certain respiratory problems, such as asthma and bronchitis.

PUT IT ON THE BACK BURNER.

We know that cooking releases particulates into the air, and that levels can remain elevated long after cooking is finished. Open a window when you cook and use the extractor fan if you have one. Put the pot on the back burner, where it will ventilate to the fan more efficiently. Keep the fan on for at least 10 minutes after cooking ends.

COOK WITH ELECTRICITY, IF YOU CAN.

It's more environmentally friendly and less polluting than gas, because gas appliances generate carbon monoxide and nitrogen dioxide. These pollutants are invisible. Good ventilation is key.

USE YOUR LOG BURNER SPARINGLY.

Open fires and older wood-burning stoves emit a mixture of gases and tiny particles. Burning wet wood is worse than dry, seasoned wood. The Department for Environment, Food and Rural Affairs (Defra) recommends burning wood that has a moisture content of less than 20 per cent, along with certain stoves that are less polluting.

DON'T GO OVERBOARD WITH CANDLES.

Candles and incense can also impact air quality. One study in Danish homes found that candles were the main source of indoor pollution. We don't know if that's the case in the UK, but lighting the odd candle isn't likely to be much of a problem.

CLEAN WITH CARE.

Cleaning products and indoor fragrances produce various volatile organic compounds which can be suspended in the air or settle in dust and on surfaces. Spray cleaning products close to the surface, then wipe with a dry cloth, then wipe again with a cloth that's been dampened in water.

FURNITURE IS ANOTHER SOURCE OF INDOOR POLLUTION.

Fabrics and certain furnishings are treated with flame retardants, and formaldehyde can be found in some furniture, floorings and building materials. Although we can't yet confidently identify the extent of any health effects that are caused, we need to establish set emission standards and a clear labelling system for these items.

GO GREEN.

Outdoor studies hint that plants can help provide a barrier against some forms of pollution, but the evidence from indoor studies is still lacking. We don't know if specific plants can reduce air pollutants in the home, but they certainly look good and are great for our wellbeing.

BE AWARE OF DAMP.

If you live in a house with damp and mould, and have a child with asthma, it can exacerbate their symptoms. Help to prevent damp by cleaning away condensation and mould, and ventilating rooms as thoroughly as possible. If your windows have trickle vents, keep them open. SF

DR JONATHAN GRIGG

Jonathan is professor of paediatric respiratory medicine and environmental medicine at Queen Mary University of London. A major report on indoor air pollution can be found at ***bit.ly/air-pollution-report***

Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

If you have an extractor fan, keep it on its highest setting while you're cooking, and open a window.

2

Your wood-burning stove might be lovely, but try to use it sparingly and fuel it with properly seasoned wood.

3

Keep an eye out for damp and mould, and tackle it before it becomes a bigger problem.

ILLUSTRATION: JACOB STEAD

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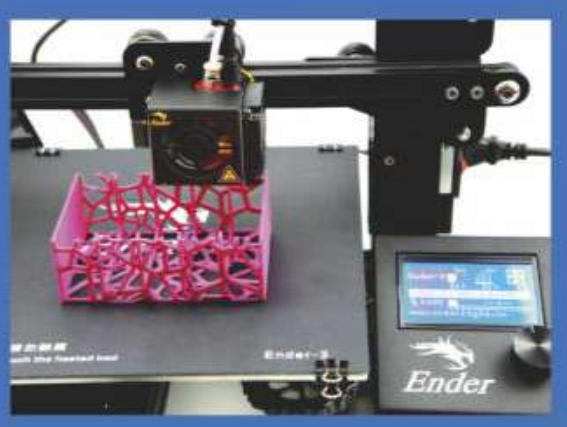

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